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THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC).

A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials.

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10 Cho-Yen/Ho

Center for Information and Numerical Data Analysis and Synthesis
Purdue University
West Lafayette, Indiana 47906

Annual Final Report - Contract 15 DLA900-79-C-1007

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Prepared for

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Annual Final Report on Contract No. DLA900-79-C-1007 covers the activities and accomplishments of the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) for the period 1 January to 31 December 1980. TEPIAC's activities reported herein include literature search, acquisition, and input of source information; documentation review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction

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20. ABSTRACT (continued)

and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. TEPIAC is one of the most efficient and cost-effective Full-Service Information Analysis Centers when evaluated on input and output volumes per budgeted dollar. During this 12-month reporting period, TEPIAC screened 740,000 abstracts, scrutinized 44,000 potentially good entries, identified 9,400 pertinent references, acquired 13,014 research documents, reviewed, coded, and catalogued 7,234 research documents, extracted and compiled 3,193 sets of property data from 927 data source documents by processing 2,455 research documents in addition to performing data evaluation, correlation, analysis, and synthesis and generating recommended reference values, and responded to 515 inquiries from government laboratories and agencies, defense contractors and other industrial organizations, and academic institutions. Furthermore, four volumes of data books of the new CINDAS Data Series on Material Properties with a total of 1,525 pages were published under multiple sponsorship. Two state-of-the-art reports with a total of 144 pages were completed and released, and one state-of-the-art report completed previously was published in the Journal of Physical and Chemical Reference Data. Seven volumes of a merged and enlarged new Basic Edition of the Thermophysical Properties Research Literature Retrieval Guide with a total of 4,801 pages were completed. The preparation of extensive computer-readable bibliographic magnetic tapes covering both thermophysical and electronic properties was completed. Six issues of the "Thermophysics and Electronics Newsletter" with a total of 66,000 copies and a promotional brochure with a total of 1,000 copies were distributed. TEPIAC staff members participated in seventeen conferences and meetings. A promotional and documentary film entitled "The Anatomy of Data" produced previously has been shown to a total of about 202 organizations.

SUMMARY

The Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) is a Full-Service Department of Defense Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University under contract with the Defense Logistics Agency (DLA). TEPIAC is under the administrative management of the Defense Technical Information Center (DTIC) and under the technical direction of the Army Materials and Mechanics Research Center (AMMRC). The objective of TEPIAC operations is to provide scientific and technical information analysis service on thermophysical and electronic properties of materials to the Department of Defense, other government agencies, government contractors, and also the private sector in areas relating to technology needs, developments, and trends.

TEPIAC's major functions are to search, collect, review, evaluate, appraise, analyze, synthesize, and summarize the available scientific and technical data and information from worldwide sources on the various thermophysical, electronic, electrical, magnetic, and optical properties of materials so as to maintain a comprehensive, authoritative, and up-to-date national data base for the use of the entire DOD community, and to disseminate the results both by providing authoritative data and information directly to the individual users through technical and bibliographic inquiry services and by publishing major reference works on property data and information for the general users at large.

TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments.

This second Annual Final Report on DLA Contract DLA900-79-C-1007 covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1980. TEPIAC's activities reported herein include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical

data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts.

TEPIAC is one of the most efficient and cost-effective Full-Service Information Analysis Centers when evaluated on input and output volumes per budgeted dollar. During this 12-month reporting period, TEPIAC screened 740,000 abstracts, scrutinized 44,000 potentially good entries, identified 9,400 pertinent references, acquired 13,014 research documents, reviewed, coded, and catalogued 7,234 research documents, extracted and compiled 3,193 sets of property data from 927 data source documents by processing 2,455 research documents in addition to performing data evaluation, correlation, analysis, and synthesis and generating recommended reference values, and responded to 515 inquiries from government laboratories and agencies, defense contractors and other industrial organizations, and academic institutions. Furthermore, four volumes of data books of the new CINDAS Data Series on Material Properties with a total of 1,525 pages were published under multiple sponsorship. Two state-of-the-art reports with a total of 144 pages were completed and released, and one state-of-the-art report completed previously was published in the Journal of Physical and Chemical Reference Data. Seven volumes of a merged and enlarged new Basic Edition of the Thermophysical Properties Research Literature Retrieval Guide with a total of 4,801 pages were completed. The preparation of extensive computer-readable bibliographic magnetic tapes covering both thermophysical and electronic properties was completed. Six issues of the "Thermophysics and Electronics Newsletter" with a total of 66,000 copies and a promotional brochure with a total of 1,000 copies were distributed. TEPIAC staff members participated in seventeen conferences and meetings. A promotional and documentary film entitled "The Anatomy of Data" produced previously has been shown to a total of about 202 organizations. A statistical summary of TEPIAC accomplishments is presented in Table 1.

TABLE 1. STATISTICAL SUMMARY OF TEPIAC ACCOMPLISHMENTS

(For the Period 1 January to 31 December 1980)

	This Period	Total as of 31 December 1980
Scope		
Properties covered	36	36
Materials covered	56,183	56,183
Scientific Documentation		
Abstracts screened	740,000	44,700,000
Relevant abstracts scrutinized	44,000	802,300
Pertinent documents identified	9,400	231,600
Documents acquired (on hand)	13,014	196,345
Documents reviewed, coded, and catalogued	7,234	160,616
Entries of codification	81,754	638,839
Sources of documents	8,842	8,842
Data Tables Generation		
Documents processed	2,455	47,310
Data source documents resulted	927	21,423
Data sets compiled	3,193	96,906
Data sets in the Evaluated Numerical Data Bank	---	4,268
Inquiry Services		
Inquiries from government laboratories and agencies	64	1,155[a]
Inquiries from defense contractors and other industrial organizations	342	4,349[a]
Inquiries from academic institutions	109	2,155[a]
Total inquiries	515	7,659[a]
Publications		
Research Literature Retrieval Guides and Supplements		
Number of volumes	7	26
Number of pages	4,801	13,059
Data Books and Handbooks		
Number of volumes	4	29
Number of pages	1,525	30,486
State-of-the-art reports and technical reports		
Number of reports	2	33
Number of pages	144	5,156
Masters Theses in the Pure and Applied Sciences		
Number of volumes	1	24
Number of pages	293	5,446
Current Awareness and Promotion Efforts		
Thermophysics and Electronics Newsletter		
Number of issues	6	54
Number of copies	60,000	326,100
Promotional brochures		
Number of brochures	1	20
Number of copies	1,000	52,650
Conferences and meetings		
Number of conferences and meetings sponsored	0	16
Number of conferences and meetings participated	17	162
Documentary film	---	1

[a] Since 1963.

PREFACE

This Annual Final Report was prepared by the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC), a Department of Defense Information Analysis Center (IAC). This Center is operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana 47906, under Defense Logistics Agency (DLA) Contract DLA900-79-C-1007. The Government Administrative Manager for TEPIAC was Mr. J.L. Blue, Headquarters DLA, and since late 1980 is Mr. J.F. Pendergast, Program Manager for Information Analysis Centers, Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. TEPIAC is under the technical direction of the Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts 02172, with Mr. R.L. Farrow as the Contracting Officer's Technical Representative. The Contract was issued by the Defense Electronics Supply Center, Dayton, Ohio, with Mrs. Frances Burke as the Contracting Officer.

The present Contract is for a period of three years from 1 January 1979 to 31 December 1981. This second Annual Final Report covers only the second year from 1 January to 31 December 1980, and its submission fulfills the contractual requirement for Item No. 0002, Sequence No. A002.

The work reported herein is credited to the collective efforts of the entire staff of the Thermophysical and Electronic Properties Information Analysis Center. Dr. Y. S. Touloukian, Director of CINDAS, and Dr. C. Y. Ho, Assistant Director-Research, have been the principal investigators.

This report has been reviewed and is approved.

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SECTION I

INTRODUCTION

The Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) is a Department of Defense Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University. Under CINDAS' operation, TEPIAC has long achieved the full operational status of a Full-Service DOD Information Analysis Center, and TEPIAC has been well oriented to the needs of its user community with its products and services well-known.

The objective of TEPIAC operations is to provide scientific and technical information analysis service on thermophysical and electronic properties of materials to the Department of Defense, other government agencies, government contractors, and also the private sector in areas relating to technology needs, developments, and trends.

The major functions of TEPIAC are to search, collect, review, evaluate, appraise, analyze, synthesize, and summarize the available scientific and technical data and information from worldwide sources on the various thermophysical and electronic (including also electrical, magnetic, and optical) properties of materials so as to maintain a comprehensive, authoritative, and up-to-date national data base for the use of the entire DOD community, and to disseminate the results both by providing authoritative data and information directly to the individual TEPIAC users through technical and bibliographic inquiry services and by publishing major reference works on property data and information for the general TEPIAC users at large.

TEPIAC's major tasks and activities include literature search, acquisition, and input of source information for maintaining the data base; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; technical and bibliographic inquiry services; and current awareness and promotion efforts.

Due to the disturbing fact that the existing data and information on material properties recorded in the scientific and technical literature are often conflicting, widely diverging, and in many cases downright erroneous, as discussed in detail later in subsection 2 of Section III, TEPIAC has traditionally stressed data evaluation, correlation, analysis, and synthesis, and the generation of recommended reference data, even though TEPIAC is a full-service information analysis center. As a result, TEPIAC can provide to its users not just the available data and information, but the evaluated correct data and information, and in many cases TEPIAC also can provide predicted data and information to the users even when the needed data and information are completely lacking and nonexisting.

Furthermore, TEPIAC has always felt that the maximum optimization of its efforts in serving the end users of data and information can best be realized through the publication of major reference works, whereby the data and information are readily available at arm's reach of the engineers, scientists, and technicians. Towards this end, TEPIAC has contributed greatly over the years by publishing a number of the most comprehensive and authoritative series of data books and handbooks. As a result, even though TEPIAC has provided excellent technical and bibliographic inquiry services to the users, these services impart only a relatively small portion of the total information and data that TEPIAC has provided to the users. The major portion of the information and data are provided to the users through TEPIAC's major publications. Consider the fact that there are 29 volumes of major data books (with a total of 30,486 pages) and 19 volumes of properties research literature retrieval guides (with a total of 8,258 pages) that have been published by TEPIAC/CINDAS over the years. From about 500 to over 1,000 copies (on the average 750 ocpies) of each of these volumes have been sold mainly to the libraries of government research and development laboratories, academic institutions, defense contractors, and other industrial organizations. It is believed conservative to assume that each volume is used only once a month by only one of the hundreds or thousands of engineers and scientists in an organization possessing any copy of our publications, who would save 20 hours (at $30 per hour including overhead expense) of his time by obtaining and using the data and information from a volume of TEPIAC/CINDAS' publications instead of generating the same data and information himself; the total savings for the Nation would thus be $259,200,000

per year. This illustrates how great a contribution TEPIAC has made to the Department of Defense and to the United States as a whole.

It is appropriate at this point to discuss briefly the importance of the knowledge of thermophysical, electronic, electrical, magnetic, and optical properties of materials covered by TEPIAC to the mission of the Department of Defense and the important role of Information Analysis Centers such as TEPIAC in national defense. The knowledge of material properties is extremely important to the mission of the Department of Defense because, first of all, the proper design of defense systems and military weapons, hardware, equipment, structures, etc. used in national defense requires a complete knowledge of the properties of materials. Consider an example that concretely demonstrates the importance and usefulness of such knowledge to the Department of Defense and, as a consequence, that the mission of the Department of Defense is accomplished in a most competent manner with such knowledge. It is well known that a thorough knowledge of thermal conductive and radiative properties of refractory, insulation, and other aerospace materials is a fundamental requirement of the design of advanced weapons such as balistic missiles and spacecraft which require thermal protection systems for their operating at extremes in temperature and require lightweight high-efficiency thermal insulation systems for cryogenic fuel in booster applications. The thermal conductive and radiative properties of refractory and composite materials used in nose cones, nozzles, and leading edges are so important that these properties determine directly the temperature level of operation, and furthermore, together with thermal expansion they determine the thermal stress and thermal shock characteristics, which are most important design considerations for high temperature applications. In short, without the knowledge of these properties, the design of spacecraft, balistic missiles, and all other similar warhead delivery systems would not have been possible, and this Nation's advanced defense systems and space programs could not be off the ground.

For the design of conventional military vehicles, tanks, airplanes, and warships or their power-plants and of various firearms ranging from small guns to heavy artilleries, the knowledge of thermal conductive, radiative, and other thermophysical properties is also very essential because their operations always involve rapid heat generation and high thermal stress and thus require efficient heat dissipation or cooling; all such processes are directly related to thermophysical properties of the materials used. Thermophysical properties of fluids

are important in the design of engine cooling system, lubricating system, fuel system, combustion and exhaust system, etc. For the design of nuclear engine used in a submarine or warship, the knowledge of the thermophysical properties of nuclear fuel materials and fuel rod cladding materials is essential since these properties determine the maximum attainable heat flux from fuel rods and the temperature level of operation, which dictate almost the entire design.

In the current advanced technology, the knowledge of thermal radiative properties as well as optical properties is most essential both in the development of high-power laser weaponery for destroying enemy's aircrafts, missiles, satellites, etc. and in the development of laser-hardened materials for protecting our aircrafts, missiles, satellites, etc. against enemy's high-power laser attack. The knowledge of thermal radiative and optical properties is also extremely important in the development of target signature recognition systems for detecting and identifying enemy's oncoming aircrafts and missiles and for identifying terrestrial objects in guidance and reconnaissance applications.

The knowledge of electronic, electrical, and magnetic properties of materials is, of course, essential for the design of all electronic devices and equipment for military applications, including, for example, those electronic devices used in military electronic communication, electronic high-speed computation, electronic guidance, control, and tracking, electronic detection and sensing, electromagnetic memory and recording, electronic surveillance, reconnaissance, and intelligence, electronic jamming, deception, and countermeasure, and those military electronic devices for energy generation, storage, conversion, and transmission. In fact, the rapid advance in electronic gadgetry in recent years is a direct result of increased knowledge of the electronic, electrical, and magnetic properties of materials, unusual or otherwise. In electronic devices, the availability of efficient heat sinks for micro-circuits is another essential requirement for their satisfactory performance, and the design of efficient heat sinks requires the knowledge of thermophysical properties. It is indeed an endless list of examples demonstrating the great importance and usefulness to the Department of Defense of the knowledge of thermophysical, electronic, electrical, magnetic, and optical properties, of which TEPIAC is responsible for coverage.

In the past, the data and information on the properties of materials, though so important, were buried in the world's enormous and ever-expanding volume of scientific and technical literature, and the scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense used no more than a small fraction of the data and information already existing. This disturbing situation has been gradually improved since the establishment of the scientific and technical Information Analysis Centers, such as TEPIAC, by the Department of Defense. TEPIAC has been conducting a continuing systematic program to dig the buried data and information and to screen and filter the current data and information out of the world's ever-increasing volume of literature and to critically evaluate, appraise, analyze, synthesize, summarize, and put the data and information in a form most useful to the users in the entire Defense community. There is no doubt that the more accurately the properties of materials are known, the more likely that a system can be designed properly and performed successfully, and that the more readily the property data and information are available, the more likely that a development program can be expedited and be completed most economically.

The important role of TEPIAC, or of any other DOD Information Analysis Center, in national defense is to assure that the Department of Defense carries out its mission timely and most effectively by serving as a focal point for authoritative expertise and maintaining a national data base within the scope of its coverage to be tapped by the Department of Defense and its contractors for solutions to technological problems and for the planning of advanced defense systems, by providing instant response to meet urgent requirements of the Department of Defense when short reaction time is essential, by serving as a vehicle for effective technology transfer within its scope, thus closing the time gap between R & D and application, by having complete cognizance of the topography of the state of knowledge within its scope, thus able to quickly identify areas where knowledge is lacking and research is required to meet existing needs and anticipated future demands, and by bring about significant cost savings to the Department of Defense and others by preventing the use of erroneous input data in critical technical applications and avoiding duplication in present and future research efforts. In short, TEPIAC and other DOD Information Analysis Centers play a very significant role in our national defense.

CINDAS, who operates TEPIAC, is a part of Purdue University, which is one of the leading institutions of higher learning in the Nation. Purdue University has numerous research laboratories in all fields and disciplines and many of these are for the measurement and research on thermophysical and/or electronic properties. Furthermore, there are over 2500 highly-trained faculty members and research specialists at Purdue. When the need arises CINDAS/TEPIAC can draw on their scientific and engineering expertise with immediate access.

Due to the fact that CINDAS' own staff, with its 13 doctoral level professional personnel, possess a very high degree of expertise in thermophysical and electronic properties, material science, solid state physics, physical chemistry, and spectroscopy, the assistance from outside CINDAS is, therefore, seldom needed. CINDAS/TEPIAC' staff have an enviable performance record of scientific and professional accomplishments through original research contributions to the primary literature. Thus they possess a high level of professional recognition and credibility in their work, which is absolutely essential for acceptance by their peers. Some of the staff have received honors and distinctions from National and International scientific and technical bodies. In the area of scientific documentation its staff comprise highly trained personnel (several staff having a degree of Master of Science) with an average of over 12 years experience in thier speciality. On its premises CINDAS has an experimental research laboratory for the measurement of thermophysical and electronic properties which is recognized as a most outstanding laboratory with a wide range of "state-of-the-art" capabilities. The work of this laboratory contributes directly to the data evaluation and analysis process, which constitutes a unique and invaluable asset to TEPIAC.

TEPIAC's accomplishments in all its tasks and activities in the performance of this contract for the 12-month period from 1 January 1980 to 31 December 1980 are detailed in the following sections.

SECTION II

SCIENTIFIC DOCUMENTATION ACTIVITIES

In order to maintain a comprehensive, authoritative, and up-to-date national data base on thermophysical, electronic, electrical, magnetic, and optical properties of materials and to provide authoritative information and data to the users with instant retrieval capability, TEPIAC has maintained a systematic program of literature search and acquisition, document review and codification, material classification, information organization, and of storing the resulting information in a computerized information storage and retrieval system. The various phases of activities in this program are discussed below.

1. LITERATURE SEARCH, ACQUISITION, AND INPUT OF SOURCE INFORMATION

The fourteen thermophysical properties under TEPIAC cognizance of information and data in all pertinent subject areas are as follows:

1. Thermal conductivity
2. Accommodation coefficient
3. Thermal contact resistance
4. Thermal diffusivity
5. Specific heat at constant pressure
6. Viscosity
7. Emittance
8. Reflectance
9. Absorptance
10. Transmittance
11. Solar absorptance to emittance ratio
12. Prandtl number
13. Thermal linear expansion coefficient
14. Thermal volumetric expansion coefficient

Originally two more properties (diffusion coefficient and surface tension) had been monitored, but these were dropped in mid-1970.

The fifteen specific electronic, electrical, magnetic, and optical properties and seven property groups under TEPIAC cognizance of information and data in all pertinent subject areas are as follows:

Properties

1. Absorption coefficient
2. Dielectric constant
3. Dielectric strength
4. Effective mass
5. Electric hysteresis
6. Electrical resistivity
7. Energy bands
8. Energy gap
9. Energy levels
10. Hall coefficient
11. Magnetic hysteresis
12. Magnetic susceptibility
13. Mobility
14. Refractive index
15. Work function

Property Groups

16. Electron emission properties
    a. Field emission
    b. Photoemission
    c. Secondary emission
    d. Thermionic emission
17. Luminescence properties
    a. Cathodoluminescence
    b. Electroluminescence
    c. Mechanical luminescence
    d. Photoluminescence
    e. Thermoluminescence
18. Magnetoelectric properties
    a. Ettingshausen effect
    b. Magnetoresistance
    c. Nernst effect
    d. Shubnikov-de Haas effect
19. Magnetomechanical properties
    a. Anisotropy energy
    b. Magnetostriction
20. Photoelectronic properties
    a. Dember effect
    b. Photoconductivity
    c. Photomagnetic effect
    d. Photopiezoelectric effect
    e. Photovoltaic effect
21. Piezoelectric properties
    a. Piezoelectric effect
    b. Pyroelectric effect
22. Thermoelectric properties
    a. Peltier effect
    b. Seebeck effect
    c. Thomson effect

As to material coverage in this documentation phase of the program, TEPIAC covers nearly all materials at all temperatures and pressures and in all environments, which are far more than what are required by the contract. The materials required by the contract to be covered for thermophysical properties include, as a minimum, metals and metal alloys, ceramics, cermets, intermetallics, polymers, and composites, and those for electronic (including also electrical, magnetic, and optical) properties to be given priority coverage include elements, inorganic compounds, alloys, intermetallics, glasses, ceramics, cermets, applied coatings, polymers, composites, and systems.

The strategy of literature search has been to use both the abstracting journals and the scientific and technical journals. A number of selected journals have been subscribed and hundreds of the journals subscribed by Purdue Libraries have been fully utilized. The top ten high-yield scientific and technical journals for thermophysical properties are noted below:

1. Physical Review
2. Journal of Chemical Physics
3. Journal of Applied Physics
4. Russian Journal of Physical Chemistry
5. Soviet Physics - Solid State
6. Inorganic Materials (USSR)
7. Physica Status Solidi
8. Applied Optics
9. High Temperature (USSR)
10. Solid State Communications

The top ten high-yield scientific and technical journals for electronic properties are as follows:

1. Journal of Applied Physics
2. Soviet Physics - Semiconductors
3. Physica Status Solidi
4. Physical Review
5. Soviet Physics - Solid State
6. Solid State Communications
7. Physics Letters
8. Journal of Physical Society of Japan
9. AIP Conference Proceedings
10. Japanese Journal of Applied Physics

In addition to searching selected technical journals, four abstracting journals covering the open literature and four government abstracting journals covering the government report literature are monitored. These are:

1. Chemical Abstracts
2. Physics Abstracts
3. Electrical and Electronics Abstracts
4. Dissertation Abstracts International
5. Scientific and Technical Aerospace Reports (NASA)
6. Technical Abstracts Bulletin (DDC)
7. U. S. Government Reports Announcements (NTIS)
8. Technical Translations (NTIS)

In monitoring these abstracting journals, computer-screened inputs have been used. About 740,000 abstracts were screened by computer using carefully designed search logics. These basic sources and other minor sources yielded approximately 44,000 hits in this 12-month period. These 44,000 potentially good entries were further scrutinized manually to yield 3,150 pertinent references on thermophysical properties and 6,250 pertinent references on electronic properties. This and other statistical data showing TEPIAC's overall scientific documentation accomplishments in this period are presented in Table 2. Table 2 shows that 101,650 research documents on thermophysical properties and 129,950 research documents on electronic, electrical, magnetic, and optical properties

TABLE 2. STATISTICAL SUMMARY OF SCIENTIFIC DOCUMENTATION ACCOMPLISHMENTS

Thermophysical Properties

	Total as of 31 Dec. 1979	This Period	Total as of 31 Dec. 1980
Potential abstracts further scrutinized	---	17,000	---
Documents identified (references in system)	98,500	3,150	101,650
Documents on hand (microfiches and hard copies)	93,474	3,272	96,746
Documents reviewed, coded, and catalogued	77,058	3,441[a]	80,499
Codification entries on all properties	316,516[b]	50,169	366,685[b]

Electronic Properties

	Total as of 31 Dec. 1979	This Period	Total as of 31 Dec. 1980
Potential abstracts further scrutinized	---	27,000	---
Documents identified (references in system)	123,700	6,250	129,950
Documents on hand (microfilms, microfiches, and hard copies)	89,857	9,742	99,599
Documents reviewed, coded, and catalogued	76,324	3,793[a]	80,117
Codification entries on all properties	113,569[c]	31,585	145,154[c]

[a] In addition to document review and codification, the technical coders in this period also completed a merged and enlarged new seven-volume Basic Edition of the Thermophysical Properties Research Literature Retrieval Guide (1900-1980) with a total of 4,801 pages.

[b] Including 28,780 codification entries on diffusion coefficient and 14,182 codification entries on surface tension.

[c] Not including the estimated 127,000 codification entries from the 49,300 research documents processed before 1973. If including those, the total number of codification entries should be 272,154 as of 31 December 1980.

have been identified and selected for the TEPIAC data base as of 31 December 1980. It is expected that on the average about 3,500 to 4,500 research documents on thermophysical properties and 6,000 to 8,000 research documents on electronic, electrical, magnetic, and optical properties will be added to the TEPIAC data base each year.

In addition to the basic sources, TEPIAC has searched certain specialized sources such as special bibliographies, compendia, conference proceedings, symposium volumes, and listings of doctoral dissertations and master theses. Of particular note is the Kobe Affiliate[a] of CINDAS at Kobe, Japan, who has served a very important input function for Far Eastern literature. Furthermore, TEPIAC has continued to develop its cooperative working arrangements on the exchange of research results and information with major national and international laboratories and institutions engaged in thermophysical and/or electronic properties research. Through these highly developed procedures and arrangements, TEPIAC has a high level of confidence in regard to completeness of its input of source information.

Recent statistics shows that research documents on thermophysical and electronic properties come from the following major sources:

	Percent
Journal articles from Purdue library subscriptions	51
Journal articles from TEPIAC subscriptions	9
Journal articles from authors	18
Journal articles from Library of Congress	3
Government reports from DDC	6
Government reports from NTIS	2
Ph.D. dissertations and M.S. theses	1
Other sources	10
Total	100%

The above listing indicates that scientific and technical journal articles and other open literature constitute about 91 percent of the total research documents and government reports constitute only about 9 percent.

TEPIAC's specialized holdings of research documents, which number 96,746 on thermophysical properties and 99,599 on electronic properties as of 31 December 1980 as shown in Table 2, constitute a unique national asset and are assuming increasing importance for rapid access to the world literature on thermophysical and electronic properties. Many of these research documents, though readily available from TEPIAC, are very difficult to obtain elsewhere especially in the

[a] This CINDAS' overseas affiliate is supported through other sources.

cases of foreign literature and special publications of limited distribution. It is our experience that literature retrieval programs which yield only bibliographies as their end product are becoming increasingly less useful because of the difficulty and time lapse involved in procuring the cited documents. To remedy this situation, TEPIAC has long been supplementing the practice of submitting bibliographic responses to literature search requests with copies of the actual documents in the form of standard microfiche or hard copy.

2. DOCUMENT REVIEW AND CODIFICATION, MATERIAL CLASSIFICATION, AND INFORMATION ORGANIZATION

As each pertinent research document was received, it was immediately microfiched and then thoroughly reviewed. Pertinent information was extracted from the document with respect to the particular property measured or treated and the temperature range, the material tested and its physical state, the subject coverage of the document, and the language used. All these except the material name were translated into mnemonic code letters, and the material was assigned a material number according to an established material classification scheme. The code letters, material number, and document number were recorded on a specially designed Coding Form (see Figure 1), and were processed subsequently by computer for storage and retrieval, and also for publication of the Research Literature Retrieval Guides. The code designations for codification of literature are given in Table 3.

Since the merging of the two originally separate thermophysical properties bibliographic information file and electronic properties bibliographic information file into a single uniform Thermophysical and Electronic Properties Information System (TEPIS) was completed in early 1980, the effectiveness of our operation has been greatly improved. This approach should prove also to be more convenient to the defense community which we serve, as the merging makes it possible for scientists and engineers to access the total TEPIAC system with greater ease and uniformity. In this 12-month period, 3,441 documents on thermophysical properties and 3,793 documents on electronic properties were reviewed, coded, and catalogued, as indicated in Table 2, even though major effort had also been devoted to complete a merged and enlarged new seven-volume Basic Edition of the Thermophysical Properties Research Literature Retrieval Guide (1900-1980) with a total of 4,801 pages. The document coding activity

Figure 1.

CODED BY: ____

DATE: ____

TECHNICAL CODING FORM

38 40 41 42 43 44

PAGE No.

Columns: 01 02 04 05 06 08 09 10 11 13 15 17 18 19 21 23 24 25 26 27 28 29 31 32 33 35 37

PROP CLASS SUBST MC D PS S T L DOCUMENT No. YEAR A O

Field
Property letter
Substance class number
Substance number
Mixture code letter
Dopant number
Physical state letter
Subject letter
Temperature letter
Language letter
Document number
Year of publication
Abstract code letter
Operation column

H 122 0016 S D N E T 069904 973 — V_2O_5 Vanadium Oxide (For Thermophysical Properties)

A S 122 0016 S D N E E 100961 973 H — V_2O_5 Vanadium Oxide (For Electronic Properties)

TABLE 3. CODE DESIGNATIONS FOR CODIFICATION OF LITERATURE

Thermophysical Properties

A - Thermal conductivity
B - Accommodation coefficient
C - Thermal contact resistance
D - Thermal diffusivity
E - Specific heat at constant pressure
F - Viscosity
G - Emittance
H - Reflectance
I - Absorptance
J - Transmittance
K - Absorptance to emittance ratio
L - Prandtl number
N - Thermal linear expansion coefficient
O - Thermal volumetric expansion coefficient

Electronic Property

AS-Absorption coefficient
DC-Dielectric constant
DS-Dielectric strength
EB-Energy band
EF-Effective mass
EG-Energy gap
EH-Electric hysteresis
EL-Energy level
ER-Electrical resistivity
HC-Hall coefficient
MH-Magnetic hysteresis
MO-Mobility
MS-Magnetic susceptibility
RI-Refractive index
WF-Work function
EP-Electron emission properties
GP-Magnetoelectric properties
LP-Luminescence properties
MP-Magnetomechanical properties
PP-Photoelectronic properties
TP-Thermoelectric properties
ZP-Piezoelectric properties

Dopant

1-Group IA & IB
2-Group IIA & IIB
3-Group IIIA
4-Group IVA
5-Group VA
6-Group VIA
7-Group VIIA & VIIIA
8-Group IVB, VB, VIB, VIIB, & VIII
9-Group IIIB, Lanthanide Series, Actinide Series
0-Other or unspecified

Physical State

C-Superconductive
D-Doped
E-Expanded
F-Fibrous or whisker
G-Gas
I-Ionized (plasma)
L-Liquid
M-Multiphase
P-Powder or fine particle
S-Solid
T-Thin or thick film

Temperature

L-Low (0 to 75 K)
N-Normal (above 75 K to 1273 K) or unspecified
H-High (above 1273 K)
F-Low + Normal + High

Form of Document

A-Coded from abstract
B-Coded from abstract, document available
H-Coded from hard copy
M-Coded from microform (microfiche or microfilm)
T-Coded from translation

Subject

D-Data
E-Experiment
G-Experiment + Theory + Data
S-Survey, review, compendium, data compilation, etc.
T-Theory

Language

C-Czechoslovakian
D-Dutch
E-English
F-French
G-German
I-Italian
J-Japanese
O-Other
P-Polish
R-Russian
S-Spanish

had resulted in a net total of 366,685 codification entries on thermophysical properties and 145,154 codification entries on electronic properties as of 31 December 1980. The latter number does not include the estimated 127,000 codification entries on electronic properties for the 49,300 documents processed before 1973 by the former EPIC. One codification entry represents usually one property of one material.

Tables 4 and 5 show the file composition for thermophysical and electronic properties, respectively, by indicating the percentages of codification entries of the various properties with respect to the total number of entries. It is noted that the percentages of codification entries for most of the properties remain fairly constant over the years.

The organization of the thermophysical and electronic properties information is by material, and thus a sound material classification scheme which can properly accommodate all materials and substances is very important. The established material classification scheme has been designed to accommodate materials and substances into similar groups, selected preferably by their chemical composition. However, because of their inherent nature, certain materials do not lend themselves to a purely chemical classification and a more logical method has been adopted to classify them, instead, by their physical form and/or use and application. The present classification scheme has been used successfully over the years for the classification of approximately 56,000 different materials and substances, for which information is available in the TEPIAC file. The end product is a most comprehensive Materials Directory, which is generated by computer.

3. COMPUTERIZED BIBLIOGRAPHIC INFORMATION STORAGE AND RETRIEVAL SYSTEM

The newly completed computerized Thermophysical and Electronic Properties Information System has been in full operation. By using the CDC 6500 and 6600 computer facility at Purdue University, to which TEPIAC is connected with three dedicated terminals, this new information storage and retrieval system is being used by TEPIAC to provide bibliographic searches for both thermophysical and electronic properties in response to specific inquiries. This new system has reduced operating costs, eliminated manual procedures, assured integrity of the information, and provided a more flexible, powerful, and responsive search capability.

TABLE 4. THERMOPHYSICAL PROPERTIES FILE COMPOSITION

Property	% File
Thermal conductivity	26.5
Accommodation coefficient	0.5
Thermal contact resistance	0.6
Thermal diffusivity	2.7
Specific heat at constant pressure	24.1
Viscosity	15.6
Emittance	3.5
Reflectance	5.9
Absorptance	1.4
Transmittance	3.7
Absorptance to emittance ratio	0.2
Prandtl number	0.5
Thermal linear expansion coefficient	10.4
Thermal volumetric expansion coefficient	1.1
Thermal radiative properties	3.3
	100%

Subject	% File
Data	64.5
Experiment	5.6
Theory	13.7
Experiment + Theory + Data	11.3
Survey, review, compendium, data compilation, etc.	4.9
	100%

Temperature Range	% File
Low (0 to 75 K)	9.2
Normal (above 75 K to 1273 K)	68.7
High (above 1273 K)	12.1
Full range (Low + Normal + High)	1.0
Unspecified	9.0
	100%

Physical State	% File
Solid	55.7
Liquid	22.8
Gas	15.2
Doped	1.1
Expanded	0.4
Fibrous or whisker	0.3
Powder or fine particle	2.2
Multiphase	2.3
	100%

Language	% File
English	73.2
Czechoslovakian	0.1
Dutch	0.1
French	2.5
German	6.4
Italian	0.6
Japanese	1.4
Polish	0.1
Russian	14.7
Spanish	0.2
Others	0.7
	100%

TABLE 5. ELECTRONIC PROPERTIES FILE COMPOSITION

Property	% File
Absorption coefficient	7.3
Dielectric constant	4.1
Dielectric strength	0.8
Energy bands	2.0
Effective mass	1.2
Energy gap	4.5
Electric hysteresis	0.3
Energy levels	4.9
Electron emission properties	2.1
Electrical resistivity	35.2
Magnetoelectric properties	2.0
Hall coefficient	2.5
Luminescence properties	3.0
Magnetic hysteresis	3.1
Mobility	2.7
Magnetomechanical properties	1.1
Magnetic susceptibility	7.9
Photoelectronic properties	1.8
Refractive index	5.0
Thermoelectric properties	6.3
Work function	1.7
Piezoelectric properties	0.5
	100%

Subject	% File
Data	54.7
Experiment	4.0
Theory	17.8
Experiment + Theory + Data	1.1
Survey, review, compendium, data compilation, etc.	22.4
	100%

Temperature Range	% File
Low (0 to 75 K)	18.3
Normal (above 75 K to 1273 K) or unspecified	76.5
High (above 1273 K)	5.0
Full range (Low + Normal + High)	0.2
	100%

Physical State	% File
Solid	67.1
Liquid	7.5
Gas	1.0
Doped	11.1
Expanded	0.0
Fibrous or whisker	0.3
Powder or fine particle	0.4
Thin or thick film	8.7
Ionized (plasma)	0.8
Superconducting	3.1
Multiphase	0.0
	100%

Language	% File
English	77.1
Czechoslovakian	0.1
Dutch	0.0
French	1.1
German	2.7
Italian	0.1
Japanese	0.9
Polish	0.1
Russian	17.6
Spanish	0.0
Others	0.3
	100%

The new system is built around an integrated file system which provides for direct access to the desired information. As a result we can more easily cross-check information in the files as well as retrieve information at a lower cost. Furthermore, this new system facilitates the preparation of computer-readable bibliographic files-magnetic tape files. The preparation of such tape files on both thermophysical and electronic properties has just been completed.

4. RESEARCH LITERATURE RETRIEVAL GUIDES AND SUPPLEMENTS

The information resulting from scientific documentation efforts on thermophysical properties is disseminated partly through the formal publication entitled "Thermophysical Properties Research Literature Retrieval Guide" and its supplements.

The Basic Edition of the Retrieval Guide which covers the publication years up to 1964 was published in 1967 and contains the resulting information from the first 33,700 research documents. Its full reference citation is as follows:

> Thermophysical Properties Research Literature Retrieval Guide, Touloukian, Y.S. (Editor), Gerritsen, J.K. (Technical Editor), and Moore, N.Y. (Coordinating Editor), Basic Edition, Books 1 to 3, Plenum Press, New York, 2936 pp., 1967.

This basic edition provides a quick access to the world literature on thermophysical properties published from 1822 to June 1964. It contains 139,305 codification entries on thirteen thermophysical properties of 45,116 materials, citing 33,700 references representing 26,562 authors and 3,600 scientific and technical journals and governmental and industrial report sources.

The information on thermophysical properties resulting from the research documents with accession numbers from 33,701 up to 60,000 is contained in the Retrieval Guide Supplement I which was published in early October 1973. Its full reference citation is as follows:

> Thermophysical Properties Research Literature Retrieval Guide, Supplement I (1964-1970), Touloukian, Y.S. (Editor), Gerritsen, J.K. (Technical Editor), and Shafer, W.H. (Managing Editor), Volumes 1 to 6, IFI/Plenum Data Corp., New York, 2225 pp., 1973.

This six-volume Retrieval Guide Supplement I contains 87,050 codification entries on sixteen thermophysical properties of 16,745 materials, citing 26,300 references published from mid-1964 to December 1970. An additional 9,000 synonyms and trade names are cross-referenced to assist the user in identifying the

materials of interest. Supplement I follows essentially the same format of presentation as the Basic Edition. However, it has been restructured for improved user convenience in that the six volumes are actually six independent Retrieval Guides, each of which is for a specific group of materials. As a result, each user group can purchase, at a reasonable cost, selected volumes of specific interest, as well as the complete six-volume set.

The bibliographic information on thermophysical properties resulting from the research documents with accession numbers from 60,001 up to 94,260 and with publication years to 1977 is contained in the Retrieval Guide Supplement II which was published in December 1979. The full reference citation for Supplement II is as follows:

> Thermophysical Properties Research Literature Retrieval Guide, Supplement II (1971-1977), Gerritsen, J.K., Ramdas, V., and Putnam, T.M. (Editors), Volumes 1 to 6, IFI/Plenum Data Co., New York, 1493 pp., 1979.

This six-volume Retrieval Guide Supplement II contains 57,108 codification entries on fourteen thermophysical properties of 11,789 materials, citing 18,557 references.

In the period between 1967 and 1980, a number of improvements and other editorial changes were introduced in the organization of the Retrieval Guide, thus creating certain inconsistencies in presentation between the Basic Edition, Supplement I, and Supplement II. Furthermore, the user was forced to perform repetitive searches in each of the three publications in order to obtain complete coverage. Hence, it was thought desirable to merge the 1967 Basic Edition and the two Supplements of 1973 and 1977 as well as add new reference citations which would update the new volume to 1980. Consequently, a merged and enlarged new seven-volume Basic Edition of the Thermophysical Properties Research Literature Retrieval Guide was prepared, which has just been completed. The manuscripts of the seven volumes will soon be shipped to Plenum Publishing Corporation at New York City for printing. The full reference citation for the new Basic Edition is as follows:

> Thermophysical Properties Research Literature Retrieval Guide (1900-1980), Chaney, J.F., Ramdas, V., Rodriguez, C.R., and Wu, M.H. (Editors), Volumes 1 to 7, IFI/Plenum Data Co., New York, 4801 pp., 1981.

This seven-volume merged and enlarged new Basic Edition contains 311,648 codification entries on fourteen thermophysical properties of 44,338 materials, citing 75,208 references published from 1900 to 1980, representing 77,117 personal authors and 543 corporate authors and 8,842 document sources including scientific and technical journals and government and industrial reports. Table 6 gives the title, number of pages, number of materials, and number of references for each of the seven volumes of the new Basic Edition of Retrieval Guide.

Table 7 shows the statistical data on thermophysical properties information from the world literature covered by TEPIAC as of 31 December 1980. It lists the number of materials in each material group, the number of codification entries for each thermophysical property, the total number of documents coded for retrieval in our computerized bibliographic information storage and retrieval system, and the total number of document sources.

The information on electronic properties resulting from scientific documentation efforts on research documents with accession numbers up to 49,400 has been published in the "Electronic Properties of Materials: A Guide to the Literature," Volume 1 (1681 pp., 1965), Volume 2 (1799 pp., 1967), Volume 3 (1917 pp., 1971), and Update (2980 pp., 1972). Since 1973, much additional new information on electronic properties has been accumulated. The bibliographic information on electronic properties resulting from the research documents with accession numbers from 49,401 up to 103,608 and with publication years to 1976 is contained in the four-volume Basic CINDAS Edition of the "Electronic Properties Research Literature Retrieval Guide," which was published in November 1979. The full reference citation for this publication is as follows:

> Electronic Properties Research Literature Retrieval Guide, Basic CINDAS Edition (1972-1976), Chaney, J.F. and Putnam, T.M. (Editors), Volumes 1 to 4, IFI/Plenum Data Co., New York, 1604 pp., 1979.

This four-volume Retrieval Guide Basic CINDAS Edition contains 110,582 codification entries on 22 electronic, electrical, magnetic, and optical properties of 9,634 materials, citing 21,808 references.

Table 8 shows similarly the statistical data on electronic properties information from the world literature covered by TEPIAC as of 31 December 1980. It lists the number of materials in each material group, the number of codification entries for each electronic property, the total number of documents coded for retrieval, and the total number of document sources.

TABLE 6. THERMOPHYSICAL PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE (1900-1980)

Volume Designation and Title	Number of Pages	Number of Materials[a]	Number of References
Volume 1 - Elements	801	340	15,884
Volume 2 - Inorganic Compounds	1,092	6,032	19,407
Volume 3 - Organic Compounds and Polymeric Materials	628	6,377	8,307
Volume 4 - Alloys, Intermetallic Compounds, and Cermets	734	12,803	7,839
Volume 5 - Oxide Mixtures and Minerals	411	4,605	6,443
Volume 6 - Mixtures and Solutions	496	5,201	8,128
Volume 7 - Coatings, Systems, Composites, Foods, Animal and Vegetable Products	639	8,980	9,200
Total	4,801	44,338	75,208

[a] An additional 8,000 synonyms and trade names have been incorporated to assist the user in identifying the material or substance of interest.

TABLE 7. STATISTICAL DATA ON THERMOPHYSICAL PROPERTIES COVERAGE OF THE WORLD LITERATURE[a]

Material Group[b]	No. of Materials as of 31 Dec. 1980	Property	No. of Codification Entries as of 31 Dec. 1980
Elements and compounds	13,996	Thermal conductivity	85,772
Ferrous alloys	4,572	Accommodation coefficient	1,758
Nonferrous alloys	13,408	Thermal contact resistance	1,984
Mixtures and solutions	5,831	Thermal diffusivity	8,728
Systems and composites	3,814	Specific heat	78,070
Polymers, rubbers, etc.	1,044	Viscosity	50,372
Refractories, slags, glasses, and ceramics	4,463	Emittance	11,462
		Reflectance	18,952
Natural products	1,080	Absorptance	4,426
Minerals	1,210	Transmittance	11,929
Applied Coatings	3,463	Absorptance to emittance ratio	549
Cermets	1,504		
Others	1,798	Prandtl number	1,680
		Thermal linear expansion coefficient	33,628
		Thermal volumetric expansion coefficient	3,597
		Thermal radiative properties	10,816
		Diffusion coefficient (to 1972)	28,780
		Surface tension (to 1972)	14,182
Total	56,183	Total	366,685

Number of Documents Coded for Retrieval	80,499
Number of Document Sources	8,842

[a] Systematic coverage retrospective to the year 1920 with earlier publications as far back as to the year 1800.

[b] These material groups are the same for both thermophysical and electronic properties.

TABLE 8. STATISTICAL DATA ON ELECTRONIC PROPERTIES COVERAGE OF THE WORLD LITERATURE[a]

Material Group[b]	No. of Materials as of 31 Dec. 1980	Property	No. of Codification Entries as of 31 Dec. 1980[c]
Elements and compounds	13,996	Absorption coefficient	10,364
Ferrous alloys	4,572	Dielectric constant	6,002
Nonferrous alloys	13,408	Dielectric strength	1,214
Mixtures and solutions	5,831	Energy bands	2,874
Systems and composites	3,814	Effective mass	1,704
Polymers, rubbers, etc.	1,044	Energy gap	6,513
Refractories, slags, glasses, and ceramics	4,463	Electric hysteresis	482
Natural products	1,080	Energy levels	7,116
Minerals	1,210	Electron emission properties	3,065
Applied Coatings	3,463	Electrical resistivity	51,137
Cermets	1,504	Magnetoelectric properties	2,846
Others	1,798	Hall coefficient	3,670
		Luminescence properties	4,414
		Magnetic hysteresis	4,440
		Mobility	3,966
		Magnetomechanical properties	1,641
		Magnetic susceptibility	11,483
		Photoelectronic properties	2,614
		Refractive index	7,268
		Thermoelectric properties	9,202
		Work function	2,428
		Piezoelectric properties	711
Total	56,183	Total	145,154

Number of Documents Coded for the New Retrieval System	30,817[c]
Number of Document Sources	8,842

[a] Systematic coverage retrospective to the year 1950 with earlier publications as far back as to the year 1826.

[b] These material groups are the same for both thermophysical and electronic properties.

[c] Not including the estimated 127,000 codification entries from the 49,300 research documents with accession numbers 101 to 49,400 (numbers 1 to 100 have not been assigned to any documents) processed before 1973. If including those, the total number of codification entries should be 272,154 and the total number of documents coded should be 80,117.

SECTION III

DATA TABLES ACTIVITIES

1. DATA EXTRACTION AND COMPILATION

As a result of the systematic and comprehensive search of literature in the scientific documentation phase of this program described earlier, the original research documents of interest to TEPIAC are uncovered. These documents are procured and studied, from which the data are extracted, scrutinized, organized, converted to be in uniform units, and homogeneously plotted and tabulated in the form of "Tables of Original Data" which present all the available experimental data and information, as the first stage toward the preparation of internally consistent tables of critically evaluated "best data" referred to as "Tables of Recommended Reference Values." Subsequently, this information is reviewed and the organized data are given a final critical evaluation. At this second stage, the experimental data are analyzed, correlated, and synthesized, and the recommended values are generated. This two-stage data processing is found by TEPIAC to be the most logical approach lending itself to greater effectiveness in bringing to the user the results of this type of painstaking research in the shortest possible time.

The detailed procedures which TEPIAC follows in data compilation as well as in data analysis and synthesis are not necessarily a matter of established routines and do vary from property to property and from one group of materials to another. There are certain principles which must be followed, however, irrespective of the type of data or materials involved. For example: (a) the data should be extracted directly from their original sources to ensure freedom from errors of transcription; (b) the characterization and physical and chemical conditions of the test specimen should be specified as clearly as possible so as to fully identify the materials tested; (c) especially for solids, the source of the material, method of fabrication, thermal history, heat, mechanical, irradiative, and other treatments of the specimen and the measuring method and conditions should be noted; (d) if a comparative measurement method is used, the material used as comparative standard and its property values should be cited; (e) the accuracy and precision of the data reported should be separately denoted; (f) the complete reference to the original work should always be cited with the data; etc. Whenever some of the above criteria cannot be satisfied

because of absence of necessary information in the original work, an attempt is made to contact the author, if possible. In the cases where data cannot be adequately evaluated by TEPIAC due to lack of required information, such data are appropriately "flagged".

In connection with its activities in data processing, TEPIAC has established, through experience, appropriate procedures of operational practice which lend to good organization of work, uniform recording and filing, and other procedures of "good housekeeping," thus assuring ready trackability of original records of processed data, which are permanent working records for reference at any time in the future. Every effort has been made and all necessary steps have been taken to ensure that the data tables production rate is the maximum possible consistent with TEPIAC's high professional standards.

Within each data tables project there are four major tasks: (a) data extraction and compilation, (b) data evaluation, analysis, synthesis, and generation of recommended reference values, (c) text preparation, and (d) preparation of a manuscript for publication.

The statistical summary of accomplishments of the task on data extraction and compilation for all material properties are presented in Table 9, which shows that in this 12-month reporting period 2,455 research documents have been processed for data extraction, yielding 927 data source references, and 3,193 data sets have been compiled. These make a grand total of 47,310 research documents processed for data extraction, yielding 21,423 data source references, and TEPIAC has compiled a total of 96,906 data sets in its data file. It is important to note that data extraction and compilation is only one of the tasks and a small part of the total efforts.

TABLE 9. STATISTICAL SUMMARY OF ACCOMPLISHMENTS OF DATA EXTRACTION AND COMPILATION

	Total as of 31 Dec. 1979	This Period	Total as of 31 Dec. 1980
No. of documents processed	44,855	2,455	47,310
No. of documents accepted as data sources	20,496	927	21,423
No. of materials compiled	10,727	303	11,030
No. of data sets compiled	93,713	3,193	96,906

In many of the research documents data are presented in graphs only. More than ten years in the past a Gerber Electronic Digitizer had been used at TEPIAC to read data points off graphs. Subsequently the Gerber Digitizer was replaced by a higher speed and more versatile Talos Electronic Digitizer/DEC Minicomputer-Data Processor for performing digitizing and more advanced data processing. The new equipment, which was purchased by funds provided by Purdue University, is in full operation. Whenever the graph is too small to give accurate readings, an attempt is made to contact the author for original data in tabular form.

2. DATA EVALUATION, CORRELATION, ANALYSIS, SYNTHESIS, AND GENERATION OF RECOMMENDED VALUES

Owing to the difficulties encountered in the accurate measurement of properties of materials and in the adequate characterization of test specimens, especially solids, the property data recorded in the scientific and technical literature are often conflicting, widely diverging, and subject to large uncertainty. Indiscriminate use of literature data for engineering and design calculations without knowing their reliability is dangerous and may cause inefficiency or product failure, which at times can be disastrous. Consequently, only critically evaluated data should ever be used. Another important TEPIAC task is, therefore, to critically evaluate and analyze the available data and information, to give judgment on the reliability and accuracy of the data, and to generate recommended values.

The procedure involves critical evaluation of the validity of the data and related information, resolution and reconciiiation of disagreements in conflicting data, correlation of data in terms of various controlling parameters, curve fitting with theoretical or empirical equations, comparison of results with theoretical predictions or with results derived from theoretical relationships or from generalized empirical correlations, etc. Besides critical evaluation and analysis of existing data, theoretical methods and semiempirical techniques are employed to fill data gaps and to synthesize fragmentary data so that the resulting recommended values are internally consistent and cover as wide a range of each of the controlling parameters as possible.

Considering the thermal conductivity data for example, in the critical evaluation of the validity and reliability of a particular set of experimental data, the temperature dependence of the data is examined and any unusual dependence

or anomaly is carefully investigated. The experimental technique is reviewed to see whether the actual boundary conditions in the measurement agreed with those assumed in the theoretical model used to define the property. It is ascertained whether all the stray heat flows and losses were prevented or minimized and accounted for. Furthermore, the reduction of data is examined to see whether all the necessary corrections were appropriately applied, and the estimation of uncertainties is checked to ensure that all the possible sources of error, particularly systematic error, were considered by the author(s). Since the primary factor contributing to unreliable and erroneous experimental results is the systematic error in the measurement, experimental data can be judged to be reliable only if all sources of systematic error have been eliminated or minimized and accounted for. Major sources of systematic error may include unsuitable experimental method, poor experimental technique, poor instrumentation and poor sensitivity of measuring devices, sensors, or circuits, specimen and/or thermocouple contamination, unaccounted-for stray heat flows, incorrect form factor, and, perhaps most important, the mismatch between actual experimental boundary conditions and those assumed in the theoretical model used to derive the value of thermal conductivity. These and other possible sources of errors are carefully considered in critical evaluation of experimental data. The uncertainty of a set of data depends, however, not only on the estimated error of the data but also on the adequacy of characterization of the material for which the data are reported.

Besides evaluating and analyzing individual data sets, correlation of data in terms of various controlling parameters is a valuable technique that is frequently used in data analysis. These parameters may include purity, composition, residual electrical resistivity or electrical resistivity ratio (if a metal), density or porosity, hardness, crystal axis orientation, degree of cold working, degree of heat treatment, etc. Applying the principle of corresponding states, reduced property values may be correlated with reduced temperature, pressure, and other reduced parameters.

Several properties of the same material can also be cross-correlated. For instance, thermal conductivity, specific heat, and density can be correlated with thermal diffusivity, and viscosity and specific heat of a gas can be correlated with thermal conductivity through the Chapman-Enskog theory or through the experimental data on the Prandtl number. For a fluid, the property of the saturated liquid can also be correlated with that of the saturated vapor.

In many cases, however, research papers do not contain adequate information for a data evaluator to perform a truly critical evaluation. In these cases, some other considerations may have to be used for data evaluation. At times, judgments may be based upon factors and considerations such as the purpose of the measurement, the motivation for the study, general knowledge of the experimenter, his past performance, the reputation of his laboratory, etc. In such cases, the data assessment becomes more or less subjective.

In data synthesis, the availability of a few reliable experimental data is necessary. If there exist a theory that has been tested and confirmed by reliable data, and thus has proven to be reliable, it can then be used for the generation of new property values or filling data gaps. It is important to note here the difference between a purely theoretical calculation and the data synthesis discussed here. Sometimes semiempirical techniques are also employed to fill data gaps. If no adequate theory is available that can be used as a guide for the synthesis of fragmentary data, graphical smoothing and synthesis may sometimes be used.

It is important to note that irrespective of how much experimental data are available, reliable information exists only after the experimental data had been critically evaluated and recommended values generated. It is because the scientific and technical literature is full of inaccurate and erroneous data; Figures 2 to 9 given below will serve as typical examples to illustrate this point and further to illustrate the generation of recommended values through data evaluation and analysis. Subsequently, Figures 10 to 27 will be shown as typical examples for data synthesis, which is a process of bringing order out of chaotic experimental observations and of generating a full field of new data based on limited fragmentary experimental information.

Figure 2 presents the experimental data and the recommended values for the thermal conductivity of titanium carbide and shows that the lower two sets of experimental data are utterly erroneous, being about five times too low at 800 K and ten times too low at 1350 K. Yet the lower two sets of data were published by a well-known scientist and were obtained by using two completely different experimental methods for measurement. Titanium carbide has been extensively used to make machine tools. If machine tool designers blindly use the lower data for design without knowing that the data are erroneous, one can imagine the serious consequence.

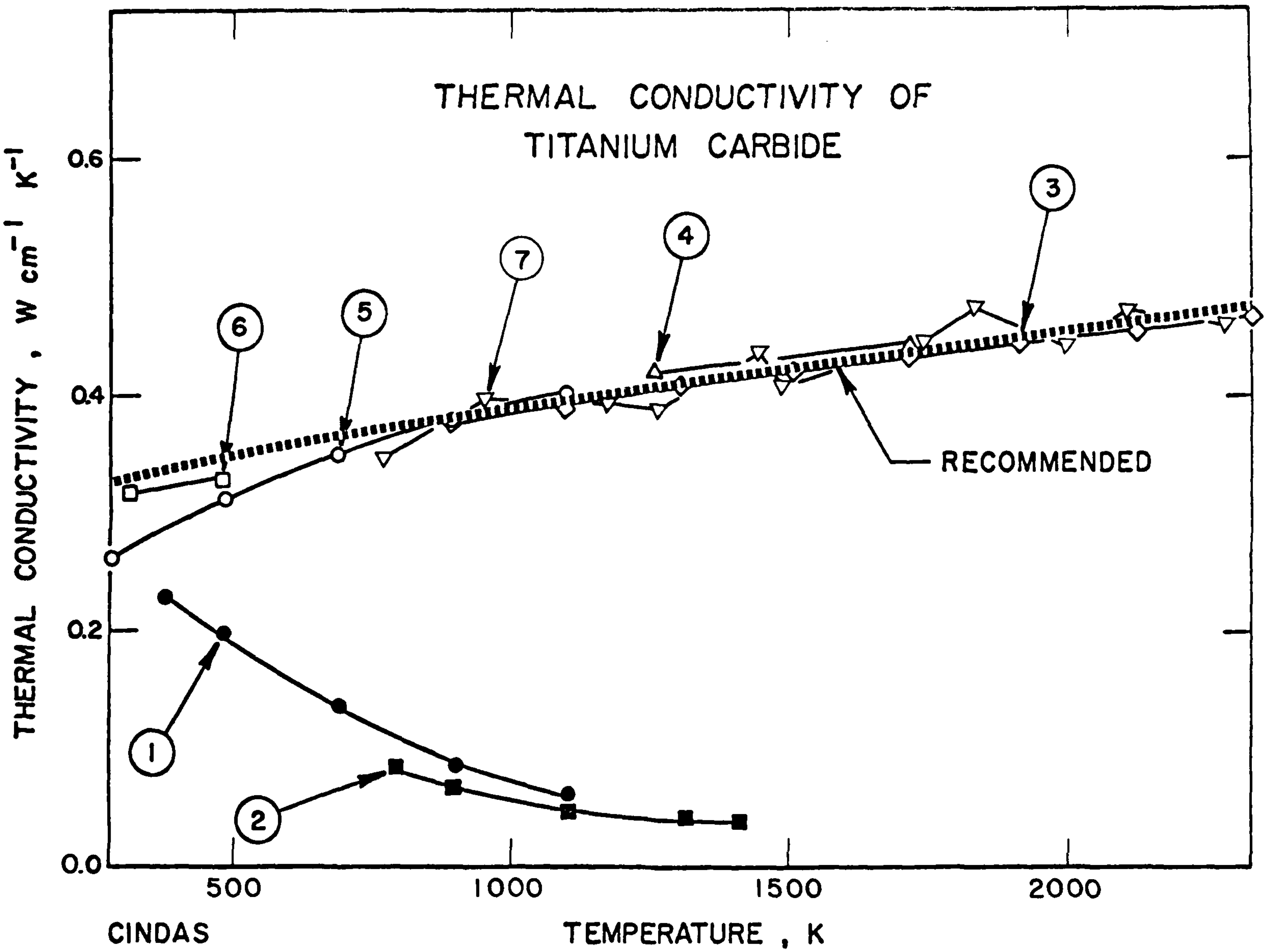

Figure 2. Experimental data and recommended values for the thermal conductivity of titanium carbide. This shows that the lower experimental data are utterly erroneous, being about five times too low at 800 K and ten times too low at 1350 K.

Figure 3 shows the experimental data and the recommended values for the thermal conductivity of platinum (60%) + rhodium (40%) alloy. This figure shows that the higher experimental data are utterly erroneous, being about 140% too high at 550 K.

Figure 4 presents the experimental data and the recommended values for the thermal conductivity of tungsten and shows that most of the experimental data are erroneous, conflicting, and widely diverging. It was estimated by a prominent scientist in 1968 that the cost of experimental research was about $30,000 per published research paper, and therefore the cost would be about $50,000 per published research paper in 1980. Since the number of published papers reporting experimental results on the thermal conductivity of tungsten is more than 100, a total of over $5,000,000 research funds had been spent to produce the confusion of experimental data shown in Figure 4. On the other hand, one can see the obvious discrepancy only when both good and bad data are at hand. In the search of literature for data, if one obtains only the portion of bad data, he won't be able to make meaningful comparison. This points out further the importance of an information analysis center such as TEPIAC/CINDAS who systematically and comprehensively collects all the available data. In this figure erroneous data are everywhere and they differ from each other in the extreme by over 300 percent. It is convincing by observing Figure 4 that the true values of the thermal conductivity of tungsten were not known until TEPIAC/CINDAS critically evaluated the discordant experimental data and generated the recommended reference values.

Figure 5 presents the experimental data and the recommended values for the thermal diffusivity of tungsten. It shows that the lower three sets of data are utterly erroneous, being about five times too low. The recommended curve shown in the figure generated in 1971 by TEPIAC/CINDAS not only gives the correct thermal diffusivity values for tungsten but also covers a full range of temperature, going far beyond the limited range covered by the discordant experimental data.

In Figure 6 the three sets of data on the thermal conductivity of nickel with data set numbers 36, 37, and 66 have extremely high slopes, and yet these are some of the most recent data published in internationally well-known scientific journals. In fact, the data of data set 66, which have an incredible nearly vertical slope, are the most recent of all the data shown in Figure 6.

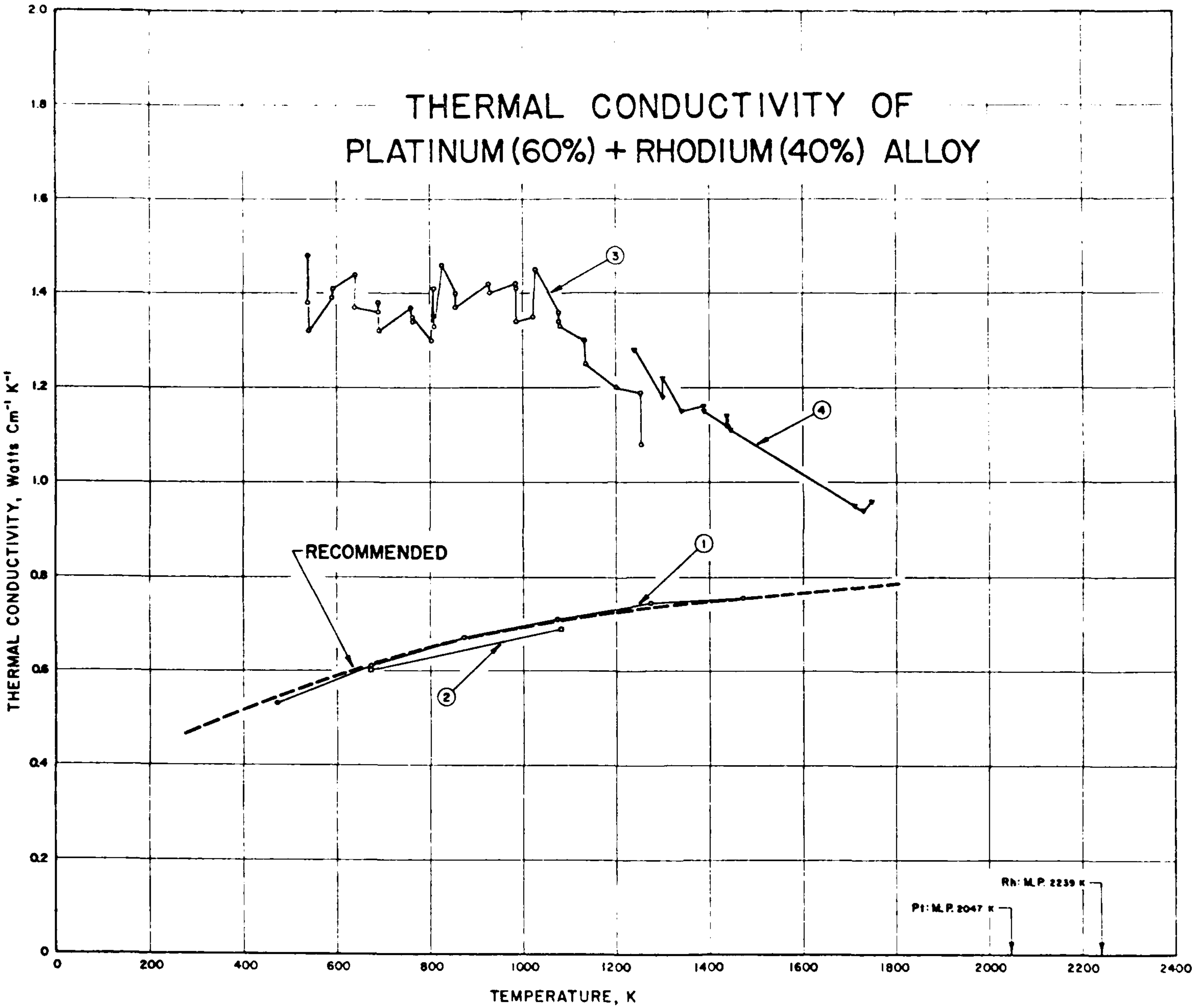

Figure 3. Experimental data and recommended values for the thermal conductivity of platinum (60%) + rhodium (40%) alloy. This shows that the higher experimental data are utterly erroneous, being about 140% too high at 550 K.

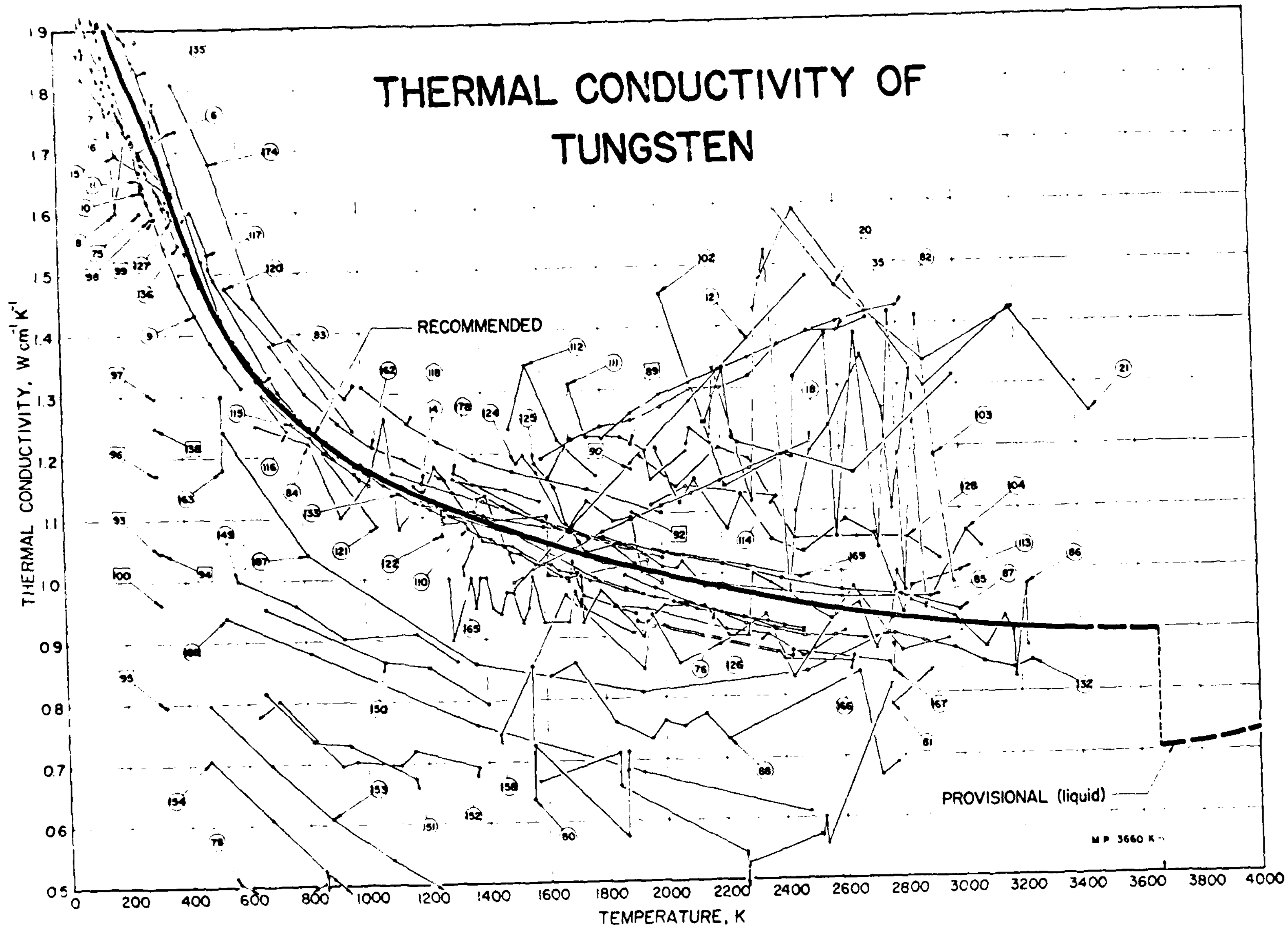

Figure 4. Experimental data and recommended values for the thermal conductivity of tungsten. This shows that most of the experimental data are erroneous, conflicting, and widely diverging.

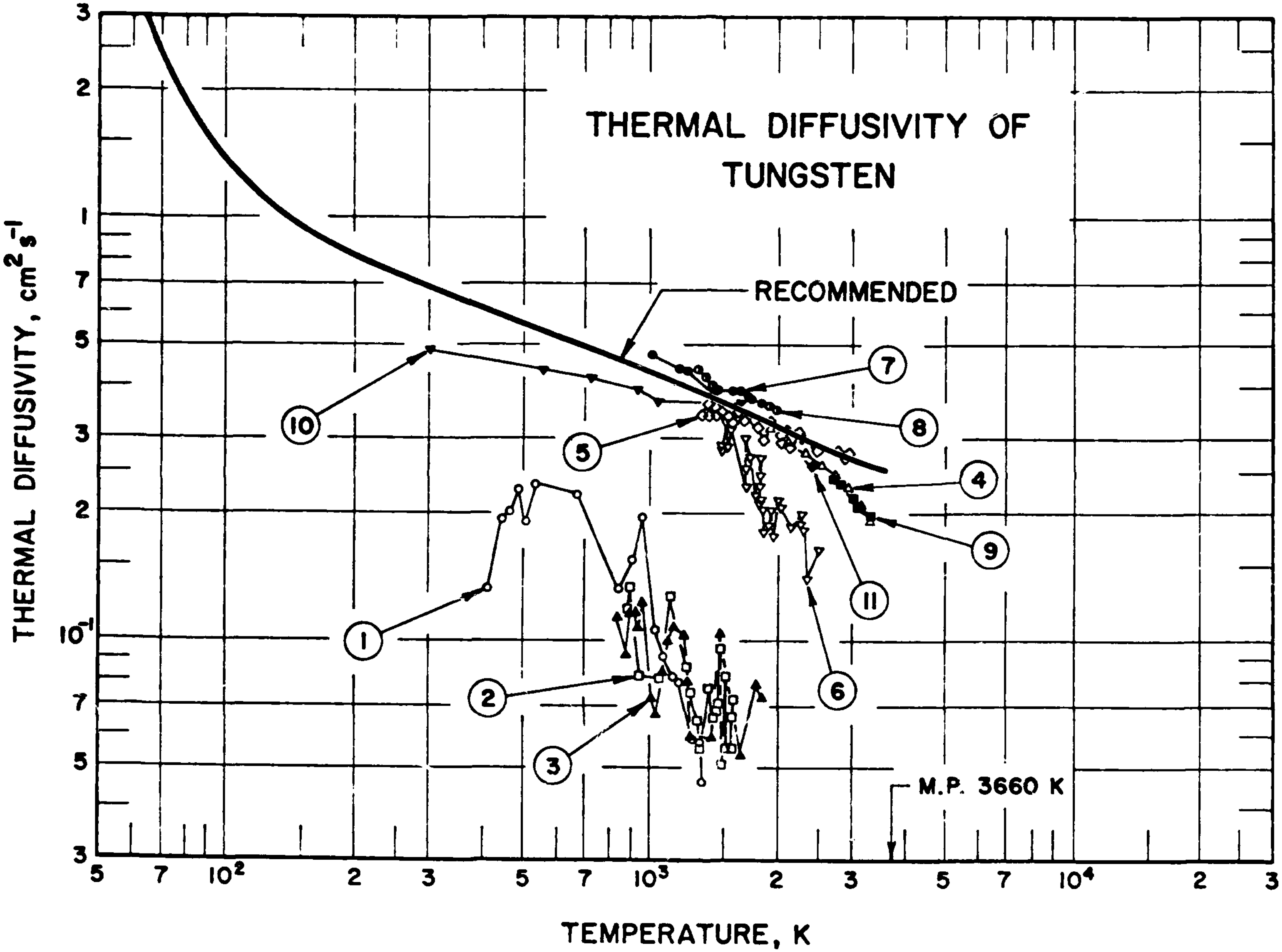

Figure 5. Experimental data and recommended values for the thermal diffusivity of tungsten. This shows that the lower experimental data are utterly erroneous, being about five times too low.

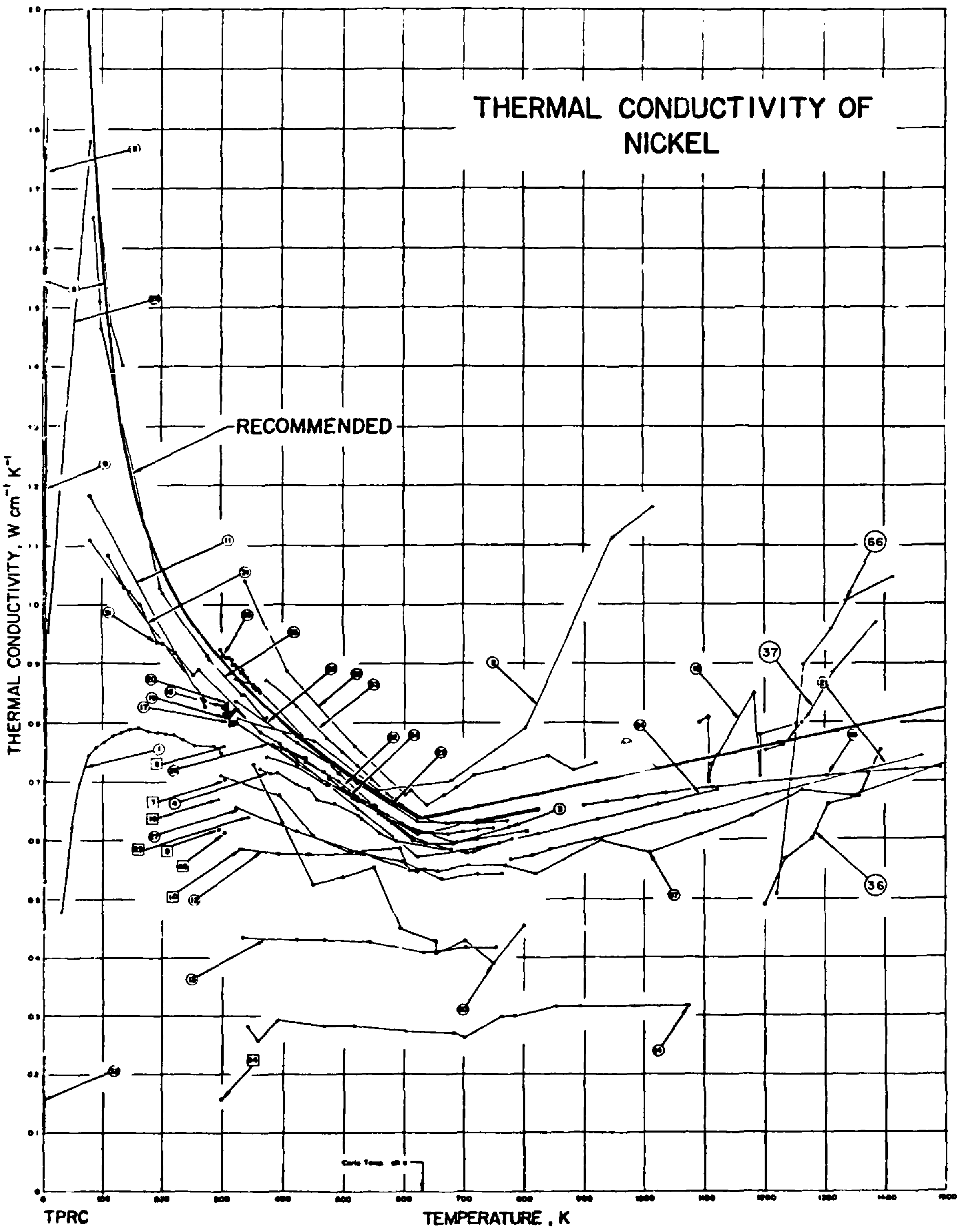

Figure 6. Experimental data and recommended values for the thermal conductivity of nickel.

One might wonder why the editors of internationally reputable scientific journals would allow such erroneous data to appear in their journals to pollute the scientific and technical information.

Not only cases of discordant experimental data showing lack of agreement are numerous, but even reference values published in well-known reference books and handbooks can be very much in error. For example, many of the thermal conductivity values published in the Metals Handbook, which is one of the most widely used and frequently consulted reference work, are in error. The Eighth Edition of the Metals Handbook was published in 1961 and the latest Ninth Edition in 1979. In the 1961 Edition of the Metals Handbook, thermal conductivity values are given for 64 elements and some other materials mainly for near room temperature. Many of these values are identical with those given in the Seventh Edition published in 1948, which covers 45 elements. Of the 64 values given in the 1961 Edition for the 64 elements near room temperature, 18 are in error by over 20 percent, 11 of the 18 are in error by over 30 percent, 8 of the 11 are in error by over 40 percent, and 5 of the 8 are in error by over 50 percent. In the 1979 Edition of the Metals Handbook, some of the erroneous values given in the 1961 Edition have been revised, partly by the adoption of CINDAS recommended values. However, some other erroneous old values are still retained in the 1979 Edition, which gives thermal conductivity values for 62 elements. Of the 62 values given in the 1979 Edition for the 62 elements around room temperature, 7 are still in error by over 20 percent, 5 of the 7 are in error by over 30 percent, 4 of the 5 are in error by over 40 percent, and one of the 4 is in error by 168 percent.

In order to show the comparison of the thermal conductivity values given in the 1961 and the 1979 Editions of the Metals Handbook with CINDAS recommended values, Table 10 lists the thermal conductivity values for 22 selected elements and also the differences in percent between the values given in the Metals Handbook and the recommended values given by TEPIAC/CINDAS. It can be observed from Table 10 that even in the latest 1979 Edition there are still many erroneous values given, which is unfortunate. It should be pointed out also that several of these erroneous values retained in the 1979 Edition such as those given for chromium, cobalt, and silicon actually have their earlier origin in the 1948 (Seventh) Edition of the Metals Handbook; that is, the same erroneous values have been repeated in all the 1948, 1961, and 1979 Editions, and no attempt was

TABLE 10. COMPARISON OF ROOM-TEMPERATURE THERMAL CONDUCTIVITY VALUES OF SELECTED ELEMENTS GIVEN IN THE METALS HANDBOOK WITH TEPIAC/CINDAS' RECOMMENDED VALUES*

Element	CINDAS (1974)	Metals Handbook (1961)		Metals Handbook (1979)	
	$\lambda (W\ m^{-1} K^{-1})$	$\lambda (W\ m^{-1} K^{-1})$	Diff.(%)	$\lambda (W\ m^{-1} K^{-1})$	Diff.(%)
Antimony	24.4	18.8	-23	25.9	6
Beryllium	201	146	-27	190	-5
Calcium	190	126	-33		
	172(200°C)			146(200°C)	-15
Carbon (graphite)	5.73 to 1960	24	319 to -99	---	---
Chromium	93.9	67	-29	67	-29
Cobalt	100	69	-31	69.04	-31
Erbium	14.5	9.6	-34	14.5	0
Gadolinium	10.5	8.8	-16	10.5	0
Gallium	40.6	29 to 38	-29 to -6	33.49	-18
Indium	83.7(0°C)			86.6(0°C)	3
	81.8	24	-71		
Iridium	147	59	-60	147	0
Iron	83.5(0°C)	75(0°C)	-10		
	80.4			80.4	0
Magnesium	156	154	-1	418	168
Neodymium	16.5(-2.22°C)	13(-2.22°C)	-21		
	16.5			16.5	0
Plutonium	6.7	8.4	25	6.5	-3
Rhenium	48.1	71.2	48	71.2	48
Rhodium	150	88	-41	150	0
Silicon	149	84	-44	83.680	-44
Tellurium	3.38 (// to c-axis)	5.9	75	3.3(// to c-axis)	-2
	1.97 (⊥ to c-axis)			2.1 (⊥to c-axis)	7
Thorium	54.0			77	43
	54.3(100°C)	38(100°C)	-30		
Titanium	37.9(-240°C)**	11.4(-240°C)		11.4(-240°C)	
	21.9				
Yttrium	17.0(-2.22°C)	14.6(-2.22°C)	-14		
	17.2			17.2	0

*Values are for room temperature unless otherwise specified.
**For polycrystalline titanium having a residual electrical resistivity of $1.90 \times 10^{-8}\ \Omega\,m$.

made to improve these values despite the availability of numerous new experimental data and of recommended reference values. However, what is even more unfortunate is the fact that the inadequacy of general handbooks and reference books as sources of data is not recognized by most users, nor is it acknowledged by editors and publishers.

The case of the thermal conductivity of chromium is an interesting example to show why and how the same inaccurate 29%-too-low value has been published in all the 1948, 1961, and 1979 Editions of the Metals Handbook and also in a number of other reference books. The author of the section on chromium in the 1979 Edition of the Metals Handbook did not indicate that he copied the same value from the 1948 or 1961 Edition of the Metals Handbook; instead, he took this "new" value from a 1973 5-volume reference work entitled "Comprehensive Inorganic Chemistry." Such a general reference work is certainly not a good source for data on material property, and the author of the section on chromium might not even be aware of the over 20 primary data sources or the sources for recommended reference values for the thermal conductivity of chromium available in the literature. It is interesting to note that the reference to the source of this value on the thermal conductivity of chromium given in the "Comprehensive Inorganic Chemistry" is a 1967 3-volume reference work entitled "Metals Reference Book" (4th Edition), and the reference to the source of this value given in "Metals Reference Book" is a 1943 compilation, which is also the source of the value given in the 1948 Edition of the Metals Handbook. It is therefore no wonder that all these (inaccurate) values are the same.

Over 150 sets of experimental data are available for the thermal conductivity of aluminum, part of which are shown, together with TEPIAC/CINDAS' recommended values, in Figure 7 in a logarithmic scale and in Figure 8 in a linear scale. The recommended values were generated through evaluation, correlation, and analysis of the available data and through semi-theoretical calculations. At low temperatures the thermal conductivity values for different specimens with small differences in impurity and/or imperfection differ greatly, and a set of recommended values applies only to a particular specimen with a particular amount of impurity and imperfection. The recommended low-temperature values shown in Figure 7 are therefore given as a family of curves, each curve being for a particular specimen with a particular amount of impurity and imperfection as specified by the corresponding value of the residual electrical

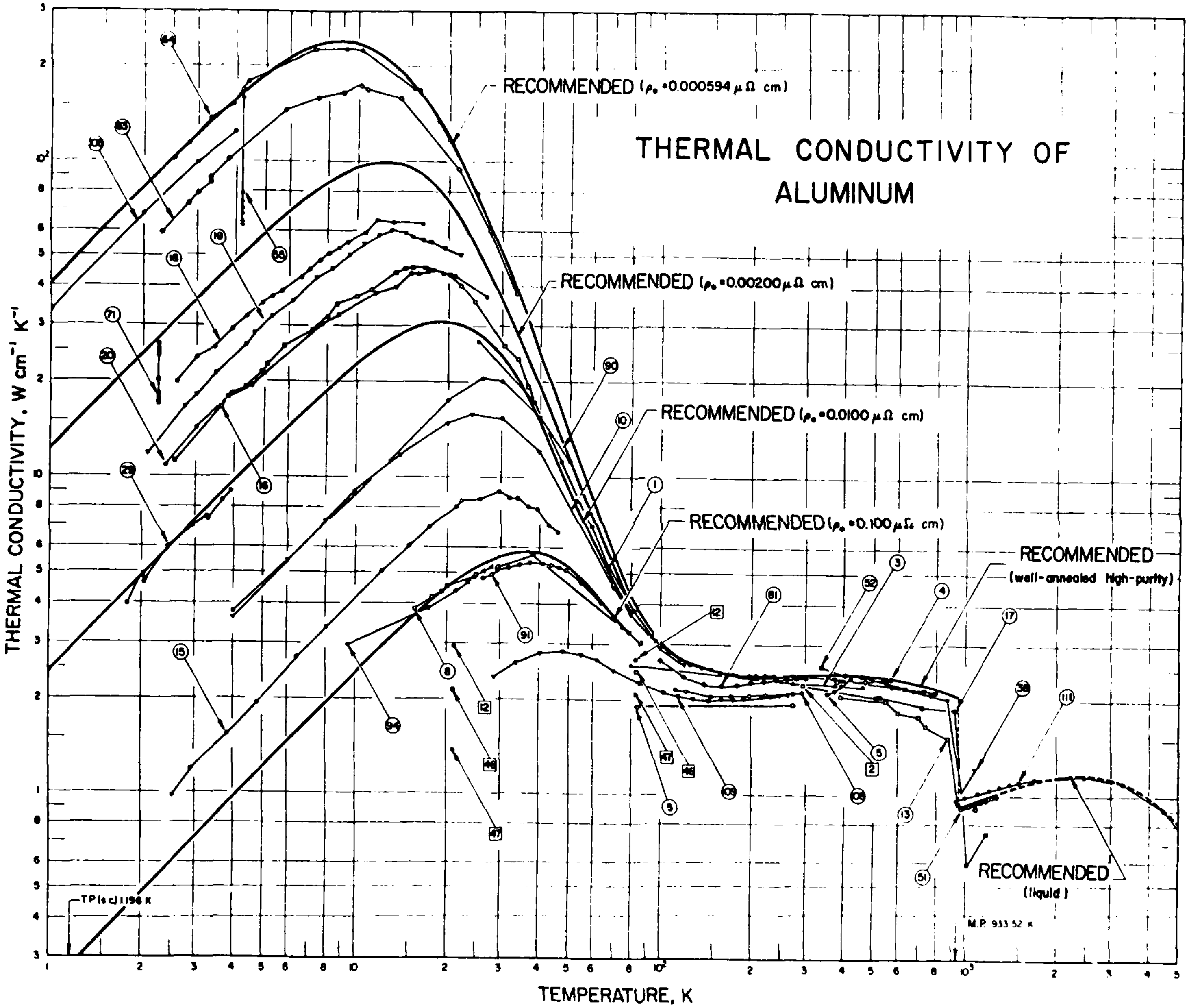

Figure 7. Experimental data and recommended values for the thermal conductivity of aluminum (logarithmic scale).

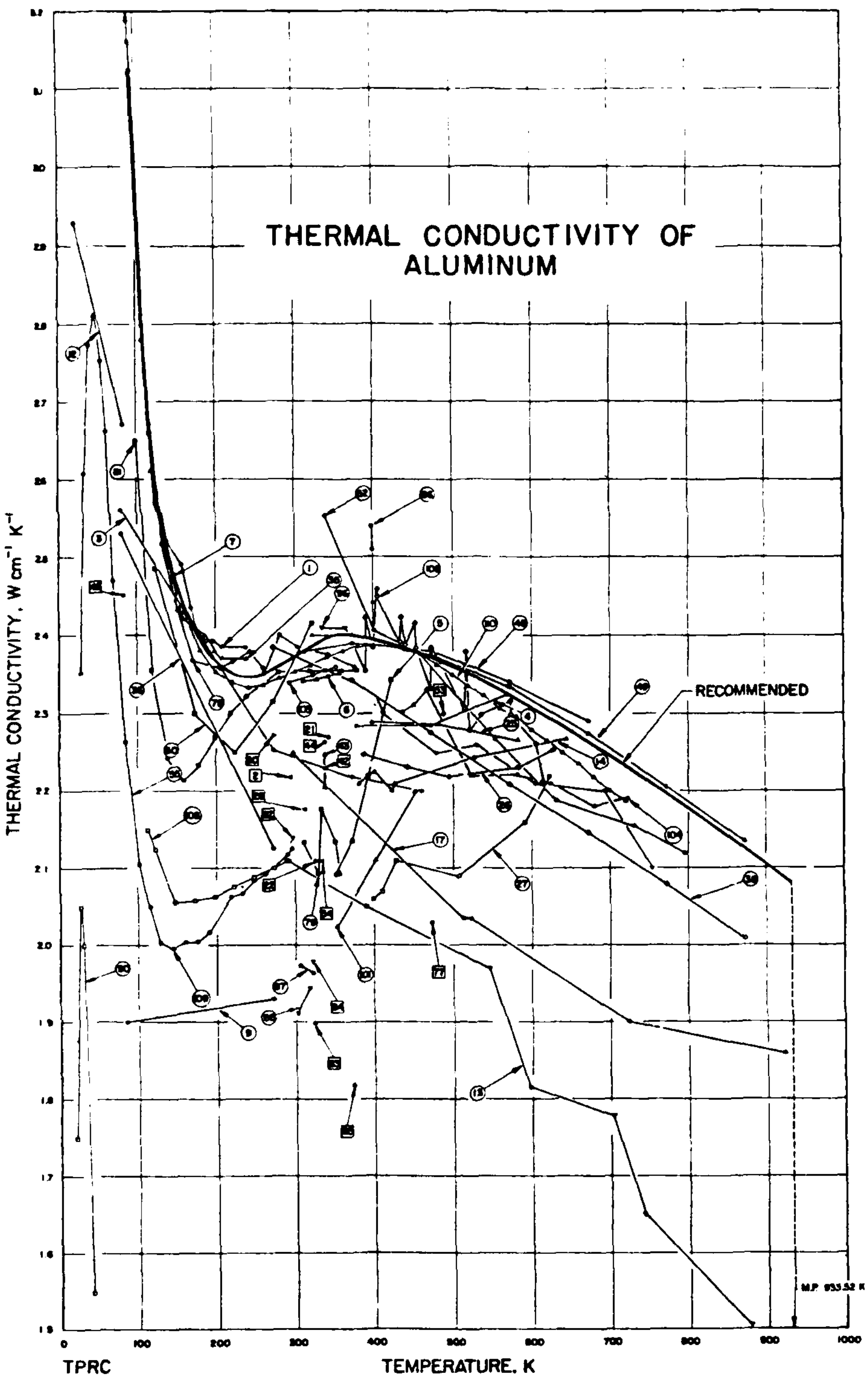

Figure 8. Experimental data and recommended values for the thermal conductivity of aluminum (linear scale).

resistivity, ρ_0, of the specimen. It can be observed in Figure 7 that each low-temperature thermal conductivity curve has a maximum, and that the purer the specimen (the smaller the ρ_0), the higher is the maximum conductivity and the lower is the temperature at which the conductivity maximum occurs. Furthermore, the locus of the thermal conductivity maxima is a straight line in a logarithmic plot, such as Figure 7. These low-temperature thermal conductivity values were calculated using reliable methods developed at CINDAS, which have been fully tested. At higher temperatures the thermal conductivity curves converge, and the thermal conductivity of high-purity aluminum can be represented by a single curve as shown in Figure 8. Figure 8 shows also clearly that the recommended values are not at all the averages of the experimental data.

Figure 9 is an old one produced in 1964 and shows almost all the thermal conductivity data for copper available in 1964 for temperatures above 100 K. It was found at that time that none of the then existing data for high temperatures can represent the thermal conductivity of high-purity copper, and it was predicted that the thermal conductivity values of high-purity copper should be those indicated by the recommended curve shown in Figure 9*. These recommended values were published by the National Bureau of Standards in NSRDS-NBS 8. Three years later, the predicted values were confirmed by accurate measurements on high-purity copper at the National Research Council of Canada; the differences between the NRC experimental data and the TEPIAC/CINDAS predicted values are mostly smaller than one percent.

The following examples are presented to demonstrate the merit of data synthesis. The available experimental data on the thermal conductivity of aluminum + copper alloys are shown in Figure 10. These fragmentary and often conflicting data were critically evaluated and analyzed. Furthermore, we had developed reliable methods for the calculations of electronic and lattice thermal conductivities of alloys. As the reliability of these methods was fully tested with selected key sets of accurate experimental data on alloys in various binary alloy systems, thermal conductivity values can be generated even if the available experimental data are very limited and fragmentary. The thermal conductivity of aluminum + copper alloys is one of such cases. The merit of data synthesis can best be appreciated by comparing the available few experimental data shown in Figure 10 and the full-range recommended values presented in Figure 11.

* The recommended curve for the thermal conductivity of copper has subsequently been slightly modified.

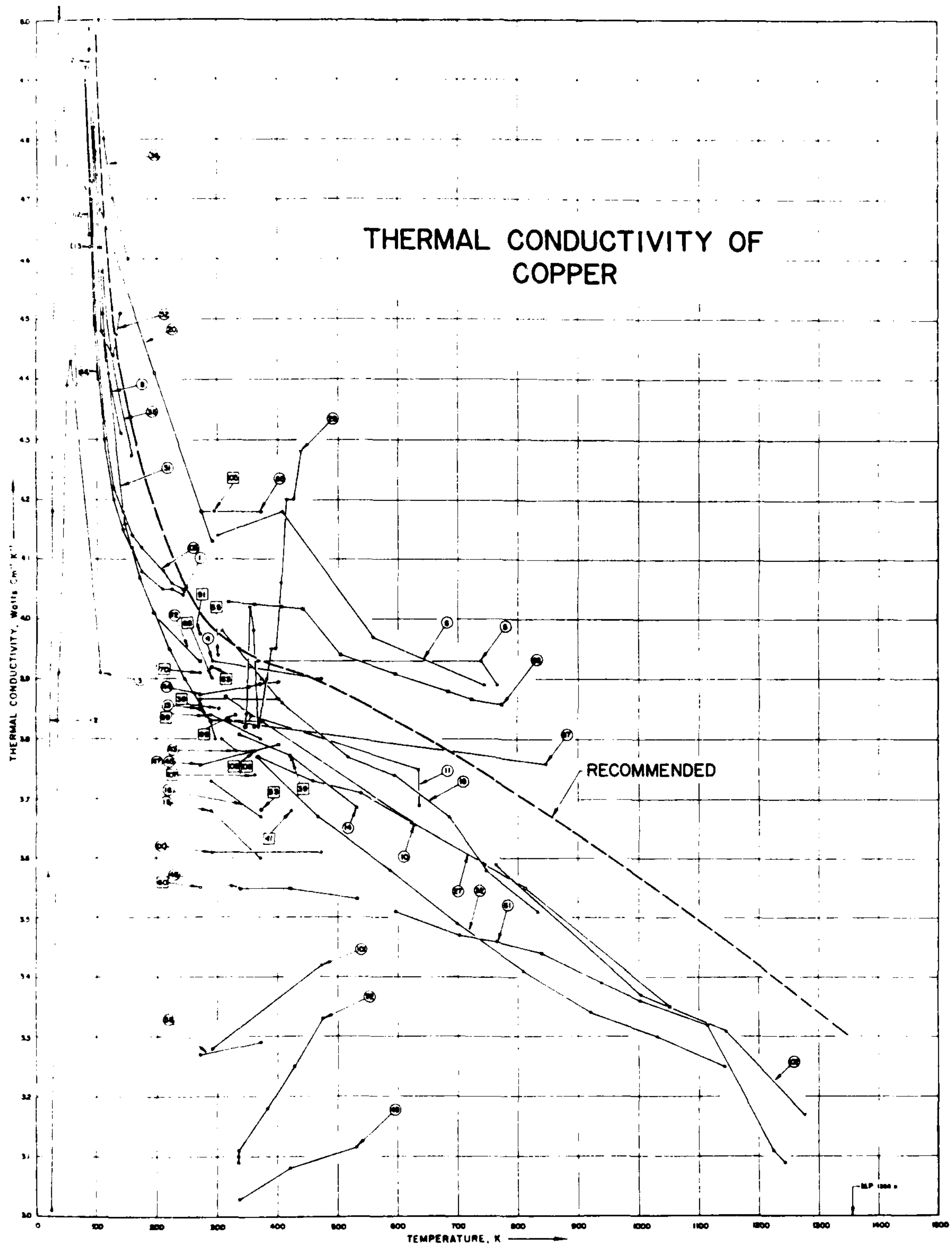

Figure 9. Experimental data and recommended values for the thermal conductivity of copper (as of 1964).

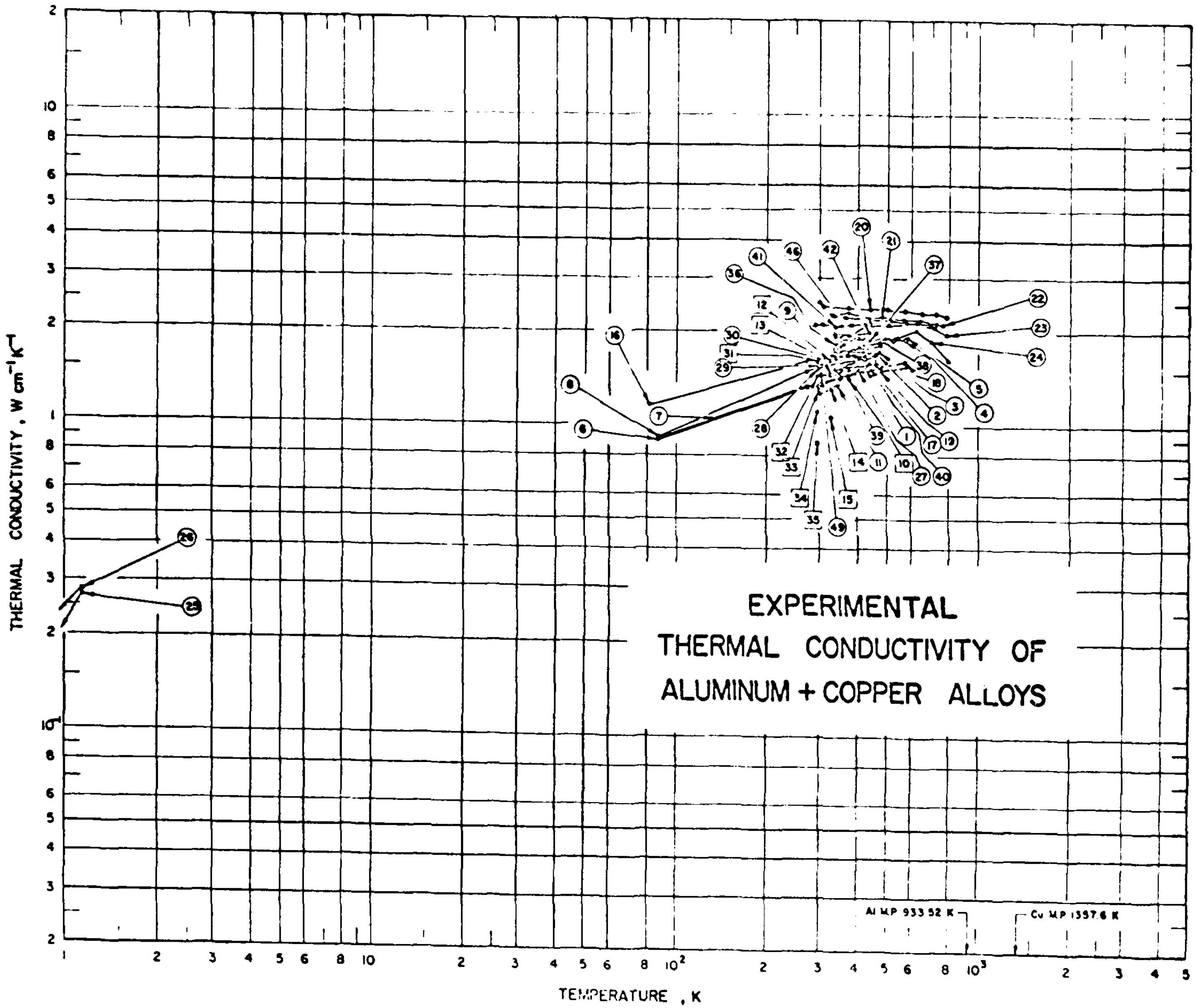

Figure 10. Experimental data on the thermal conductivity of aluminum + copper alloys. These experimental raw data are very limited, fragmentary, and conflicting.

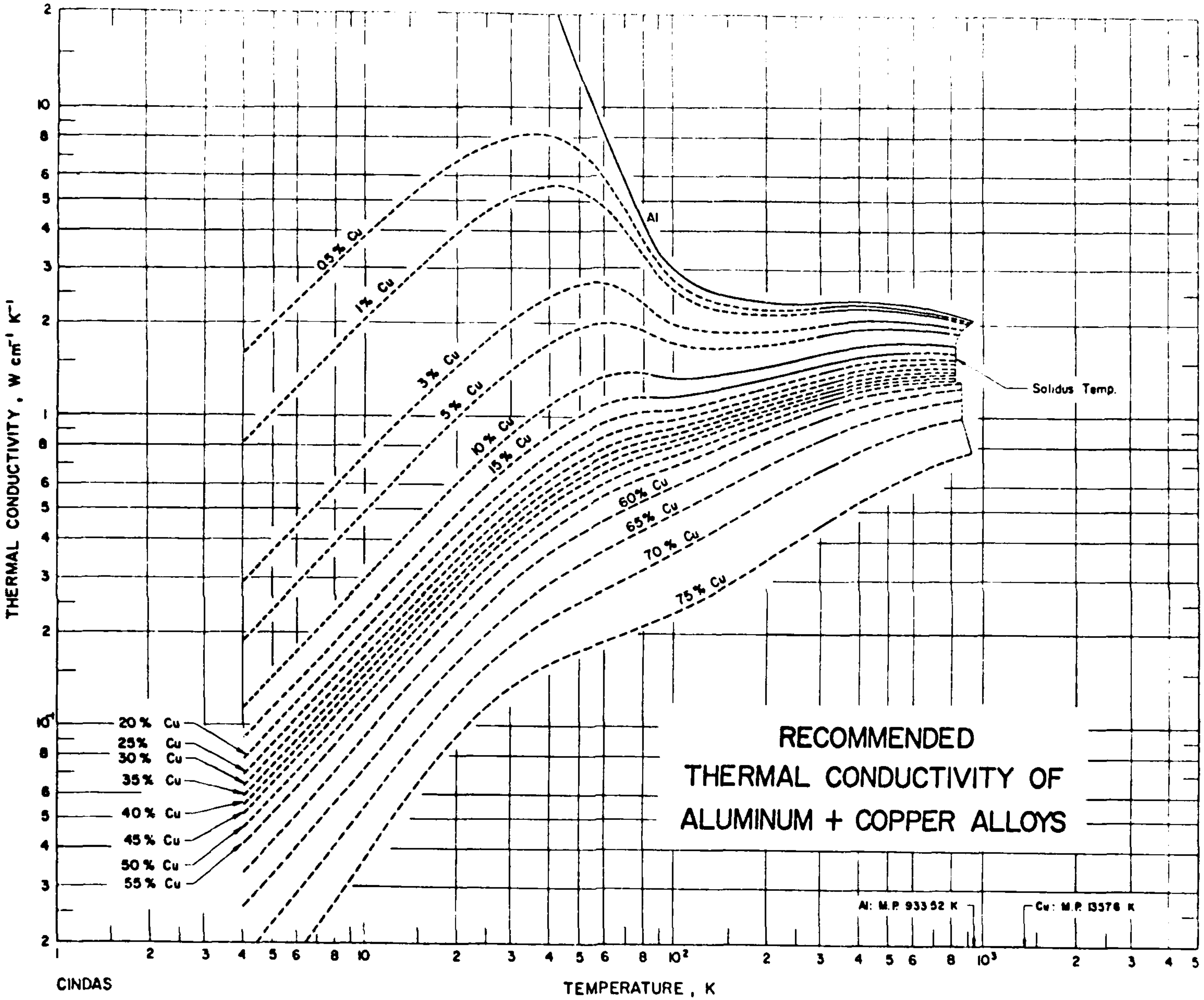

Figure 11. Recommended values for the thermal conductivity of aluminum + copper alloys. These recommended values were generated through data evaluation, analysis, synthesis, and semi-theoretical calculations based on the very limited experimental raw data shown in Figure 12 and on the available data on the electrical resistivity.

Figure 12 shows the available experimental data on the electrical resistivity of nickel + copper alloys. These data were likewise critically evaluated, analyzed, and synthesized. In analyzing the electrical resistivity data for alloys, in some cases the intrinsic resistivity and residual resistivity were analyzed separately and then were combined with the amount of the deviation from the Matthiessen's rule to obtain the total electrical resistivity. The resulting recommended values are presented in Figure 13 which cover a full range of temperature and composition. The Curie temperature of each alloy is also shown in Figure 13.

Figure 14 shows the available experimental data on the thermoelectric power of nickel + copper alloys. From these limited data, recommended values were generated to cover a full range of temperature and composition as presented in Figure 15. Comparison of Figures 15 and 13 shows that the magnetic transition (around the Curie temperature) has a more remarkable effect on the thermoelectric power of these alloys than on the electrical resistivity.

Figure 16 shows the available experimental data on the normal spectral emittance of Inconel, which shows that this property can be almost any value, from near zero to near one (the upper limit), depending largely on the surface condition of the material. These data were critically evaluated and analyzed, and the resulting analyzed data are shown in Figure 17. The systematic variation of this property with the surface condition of the material is clearly shown in this analyzed graph. It shows that the spectral emittance of the most smooth surface is the lowest, increases with increasing surface roughness, and further increases and becomes undulatory when the surface is oxidized; the latter is due to the absorption band of the resulting oxides. By comparing Figures 16 and 17, one would be further convinced that data analysis is a power tool to bring order out of very chaotic experimental observations.

The refractive index (n) of alkali halides has received few measurements. Of the twenty alkali halides, sufficient data are available for only six. On a number of them measurement has been made only at one single wavelength. The available information is even less for its temperature derivative (dn/dT) and wavelength derivative (dn/dλ). Only seven of the twenty alkali halides have received attention and no measurement has ever been made on thirteen of them. However, by using theoretical and semi-empirical techniques in data analysis and synthesis, we are able to generate the refractive index and its temperature

and wavelength derivatives for all the twenty alkali halides over the full wavelength range. Figure 18 shows the two experimental data points (the lower one of which is far off) available for the refractive index of lithium chloride and our recommended and provisional values which cover the full range of wavelength. No experimental data on the temperature and wavelength derivatives of the refractive index of lithium chloride are available, however we were able to generate predicted values for both of these two derivatives covering the full range of wavelength through correlation, prediction, and semi-theoretical calculation. Similar work has been done for the other alkali halides. In so doing we have generated recommended or predicted values for the refractive index, its temperature derivative, and its wavelength derivative of all the twenty alkali halides, which are shown respectively in Figures 19, 20, and 21.

Figures 22 and 23 show all the available experimental data on the refractive index of silicon for the wavelength and temperature dependences, respectively. From these fragmentary and often conflicting data, recommended values were generated as presented in Figure 24 which cover a full range and are as a function of both wavelength and temperature. Such a complete spectrum of values on the refractive index of silicon is for the first time ever available. Similarly, Figure 25 presents the recommended values for the temperature derivative of the refractive index of silicon as a function of both wavelength and temperature.

It should be apparent from the above illustrations that data evaluation, correlation, analysis, and synthesis is a very powerful tool which not only can clean up a body of conflicting and chaotic experimental data to come up with correct values, but also can create new data and new knowledge, which in itself is a major contribution to science and technology. Thus, TEPIAC can provide to the user not just the available data and information (which is usually the limit that an ordinary information center can do), but the evaluated correct data and information, and furthermore, in many cases TEPIAC can also provide predicted data and information to the user even when the required data and information are completely lacking and nonexisting. This is why TEPIAC has traditionally always stressed data evaluation, correlation, analysis, and synthesis and the generation of recommended reference data.

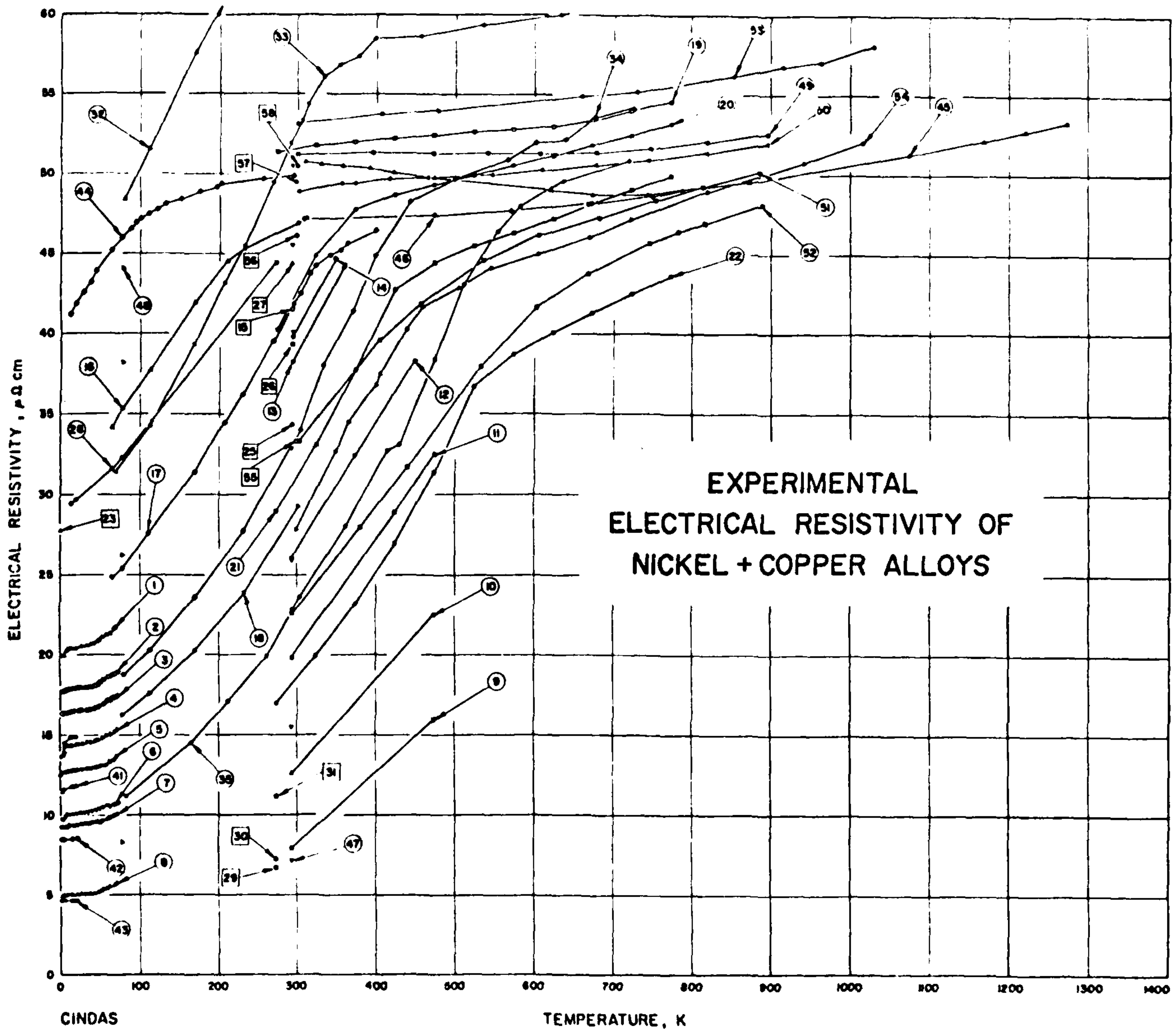

Figure 12. Experimental data on the electrical resistivity of nickel + copper alloys.

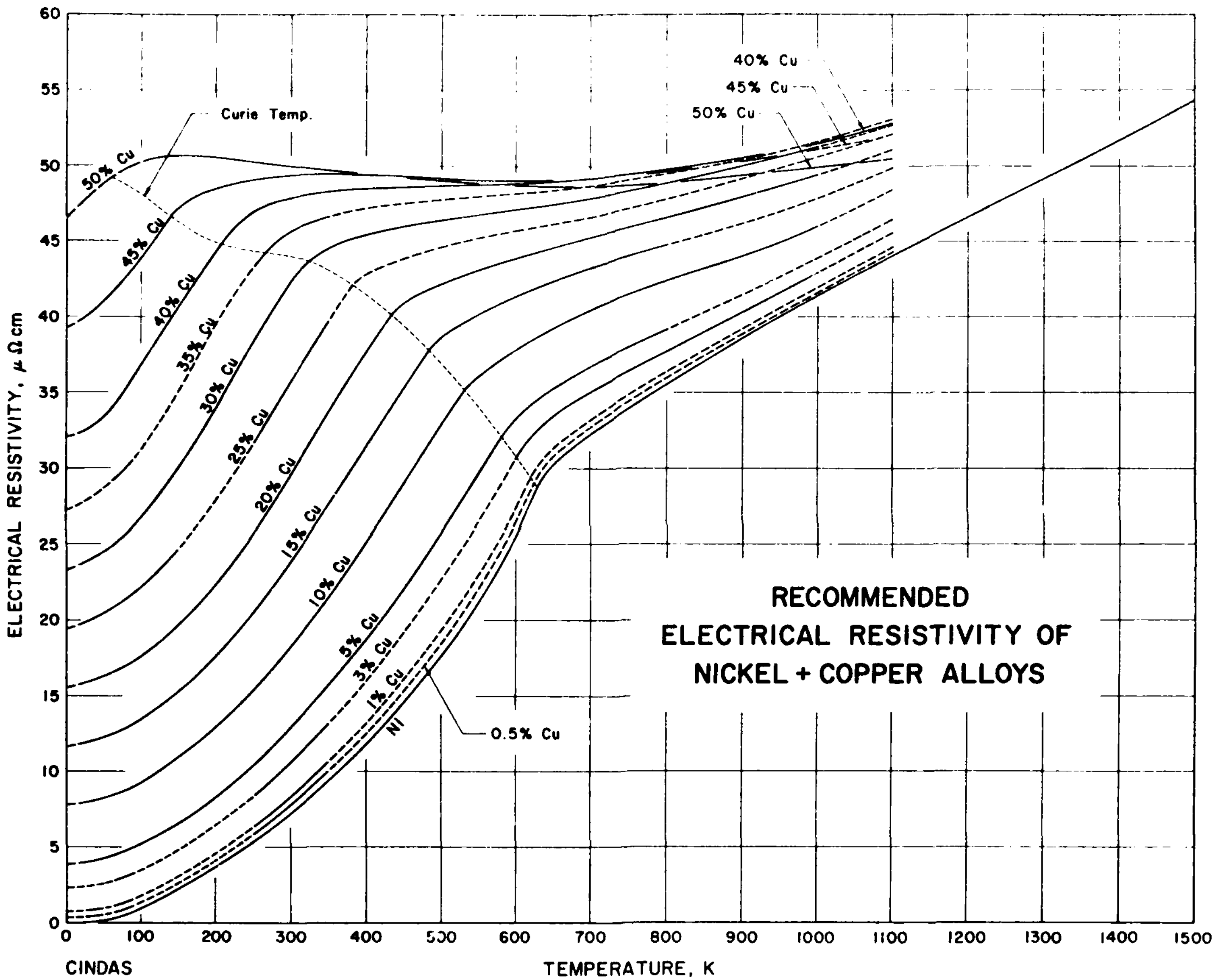

Figure 13. Recommended values for the electrical resistivity of nickel + copper alloys.

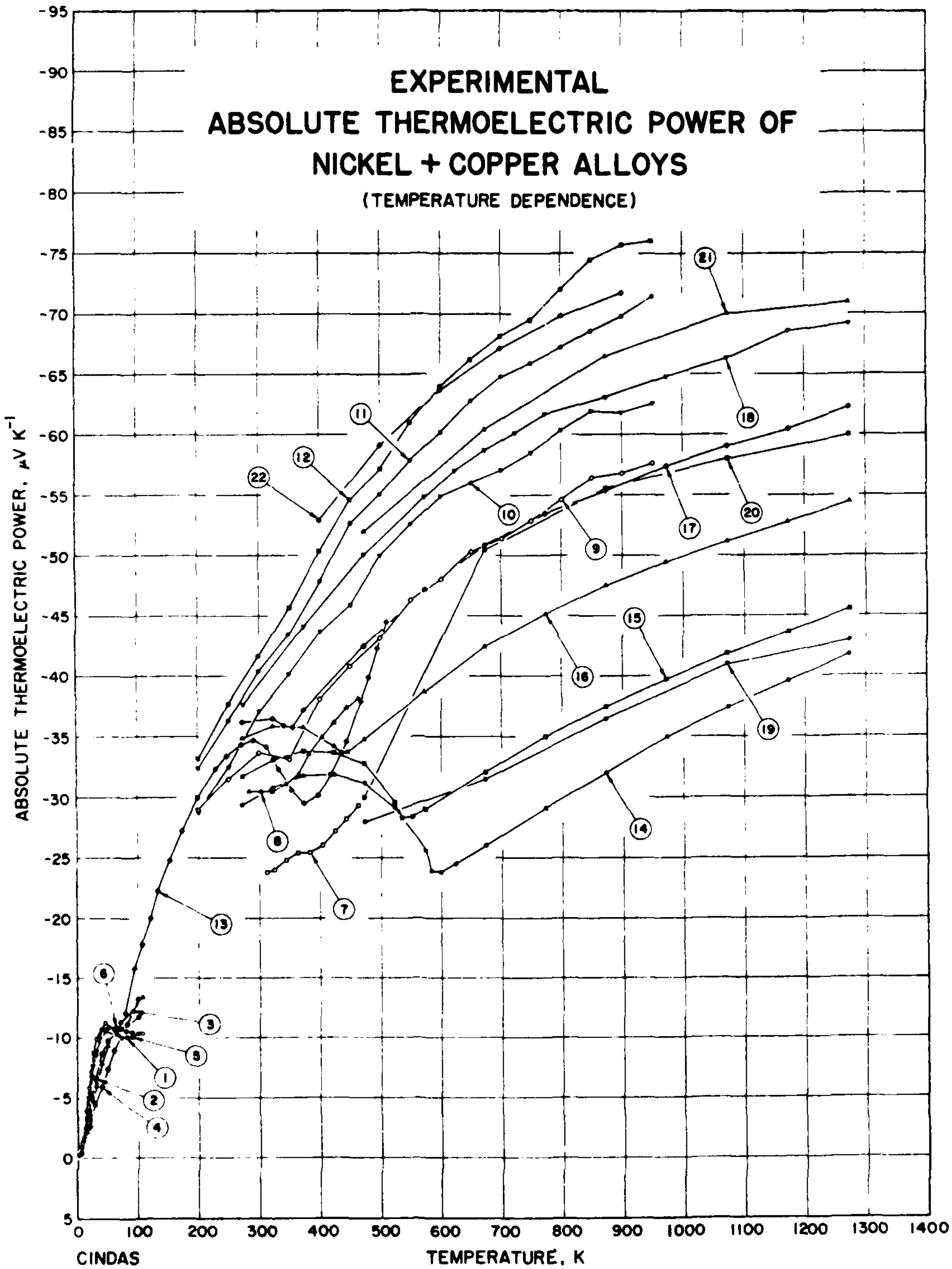

Figure 14. Experimental data on the absolute thermoelectric power of nickel + copper alloys.

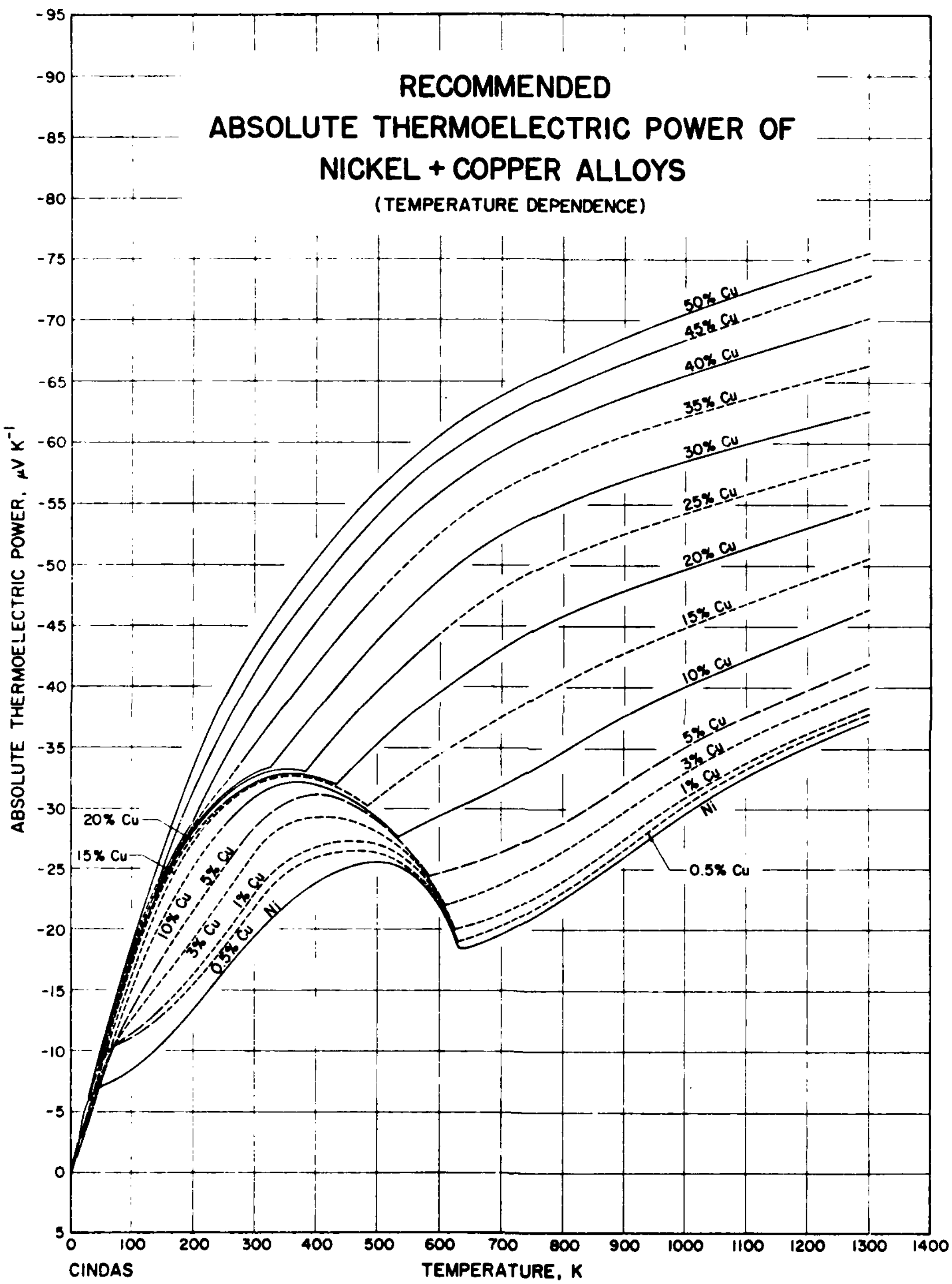

Figure 15. Recommended values for the absolute thermoelectric power of nickel + copper alloys. These recommended values were generated through data evaluation, correlation, analysis, and synthesis from the limited experimental raw data shown in Figure 14.

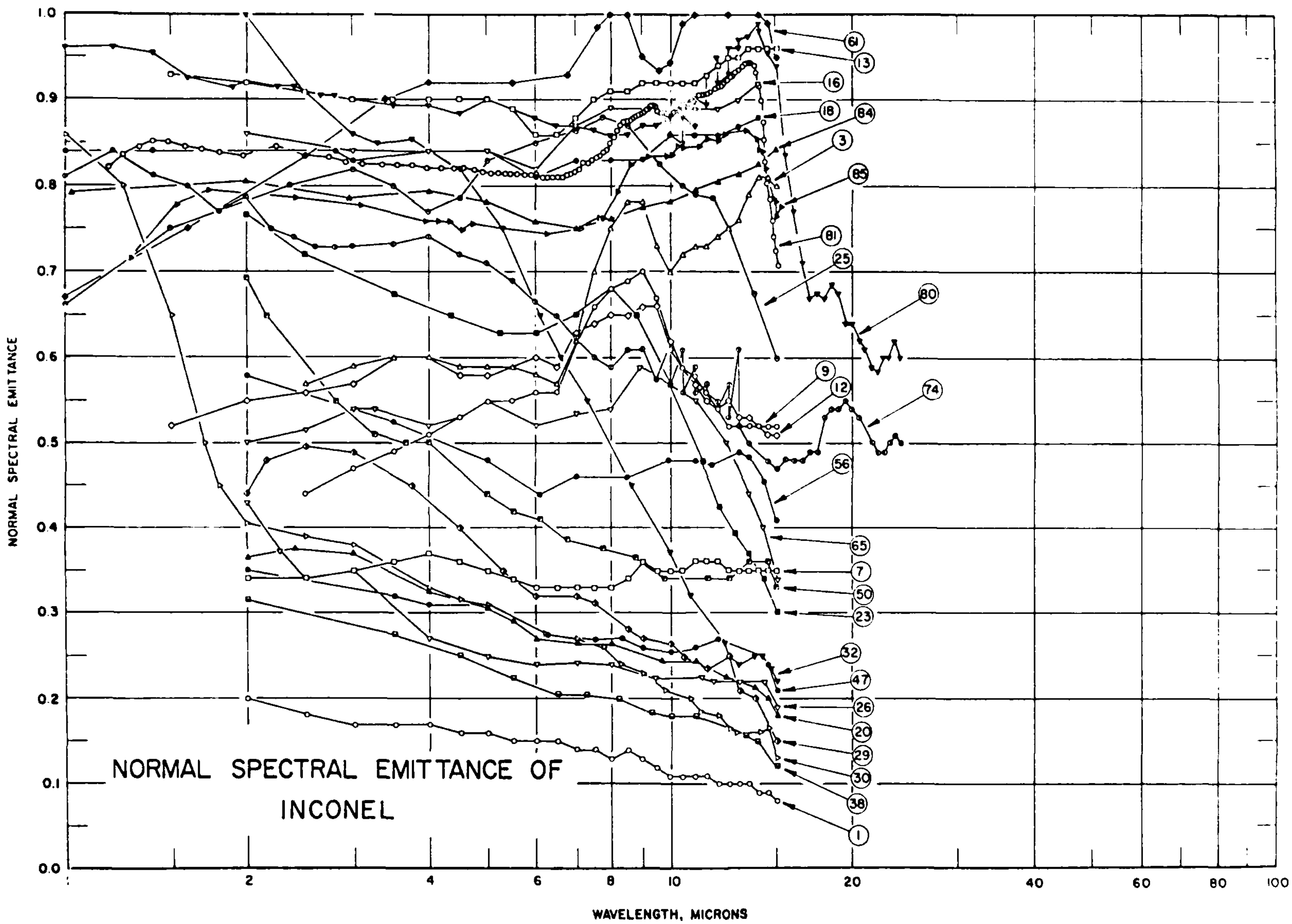

Figure 16. Experimental data on the normal spectral emittance of Inconel.

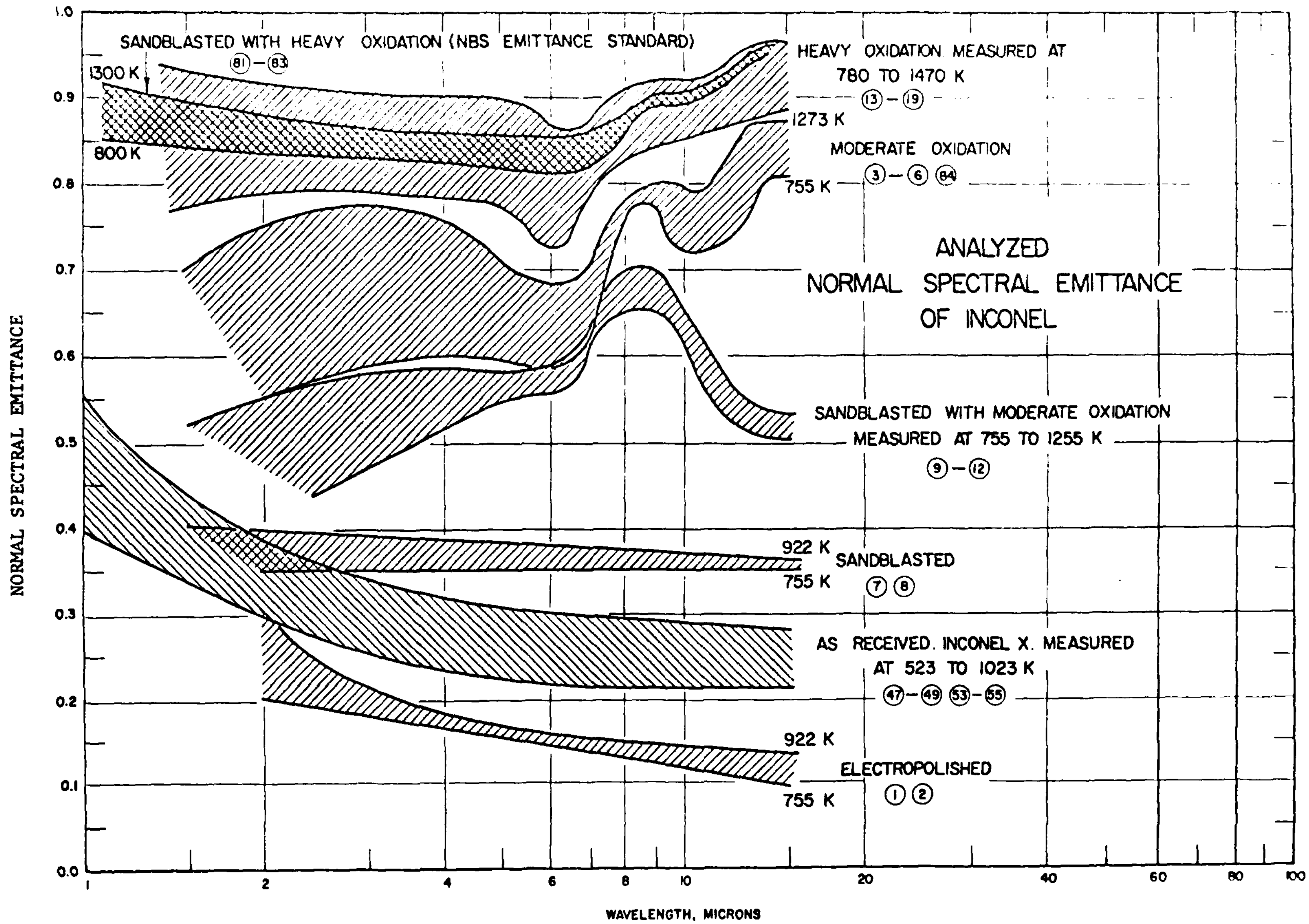

Figure 17. Analyzed data on the normal spectral emittance of Inconel.

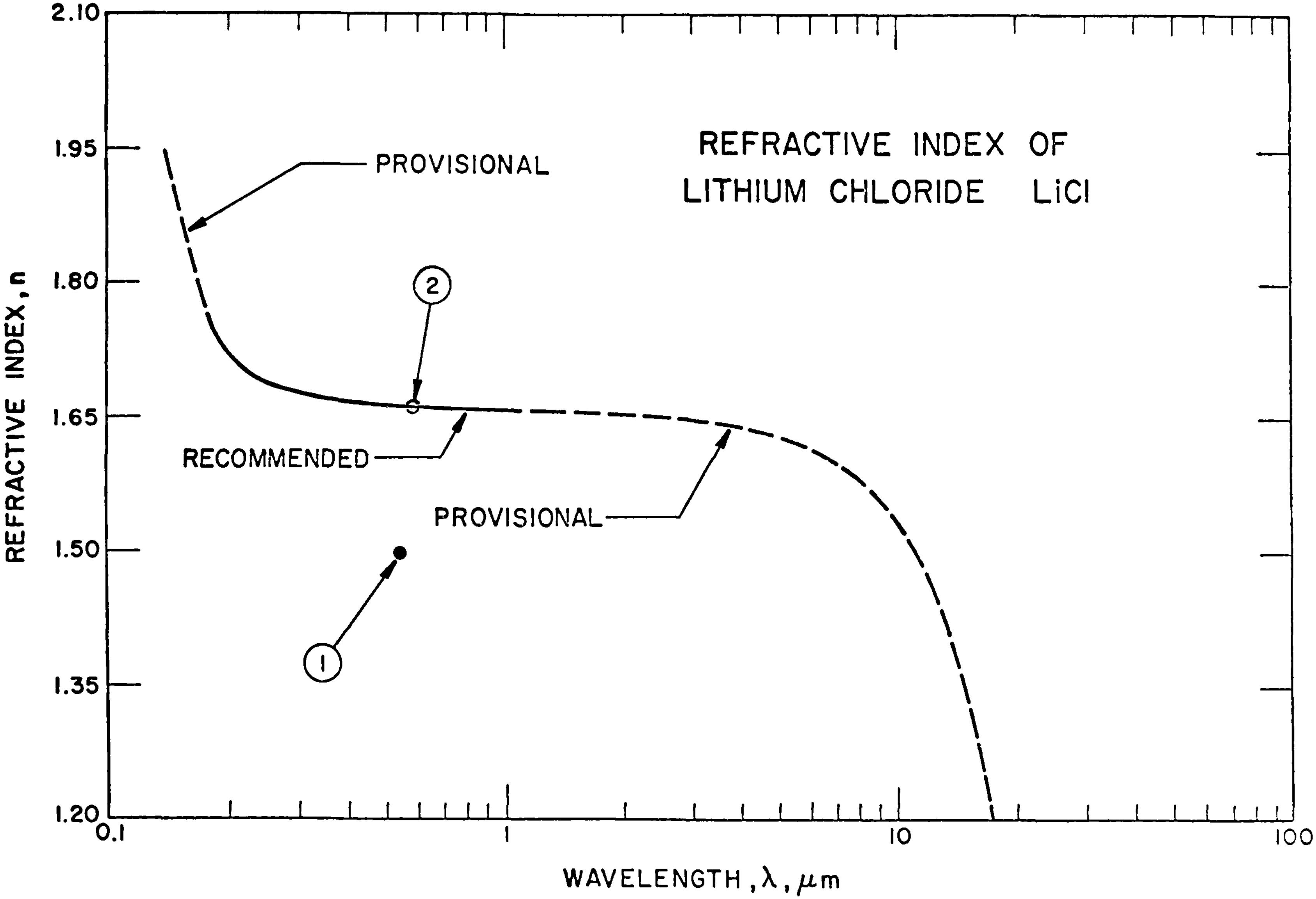

Figure 18. Experimental data and recommended and provisional values for the refractive index of lithium chloride. The lower experimental data point is far off. The full-range values are generated through data synthesis, correlation, and semi-theoretical calculation.

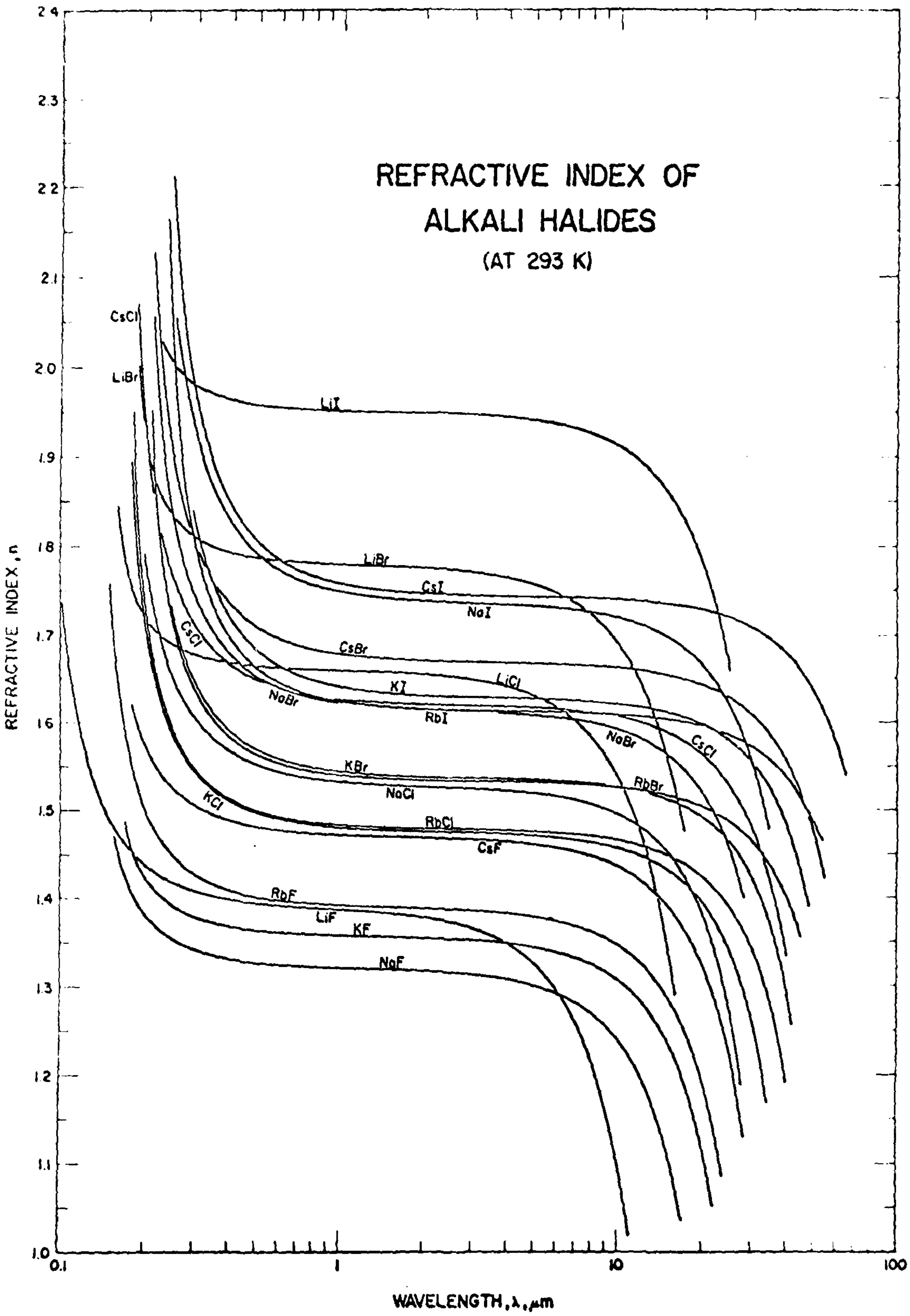

Figure 19. Recommended and provisional values for the refractive index of all twenty alkali halides. Most of the values are generated through synthesis, correlation, prediction, and calculation.

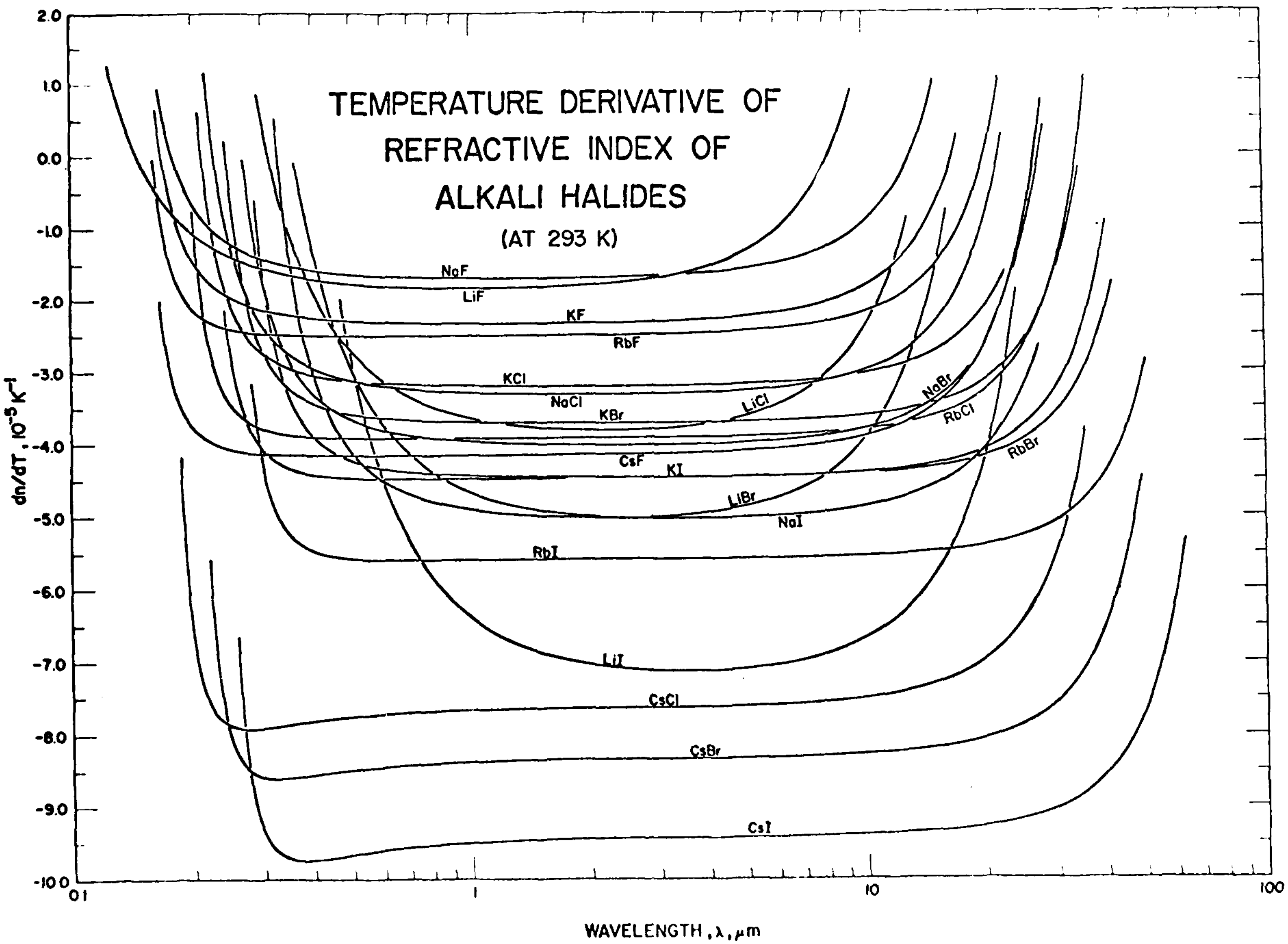

Figure 20. Recommended and provisional values for the temperature derivative of the refractive index of all twenty alkali halides. Most of the values are generated through correlation, prediction, and calculation.

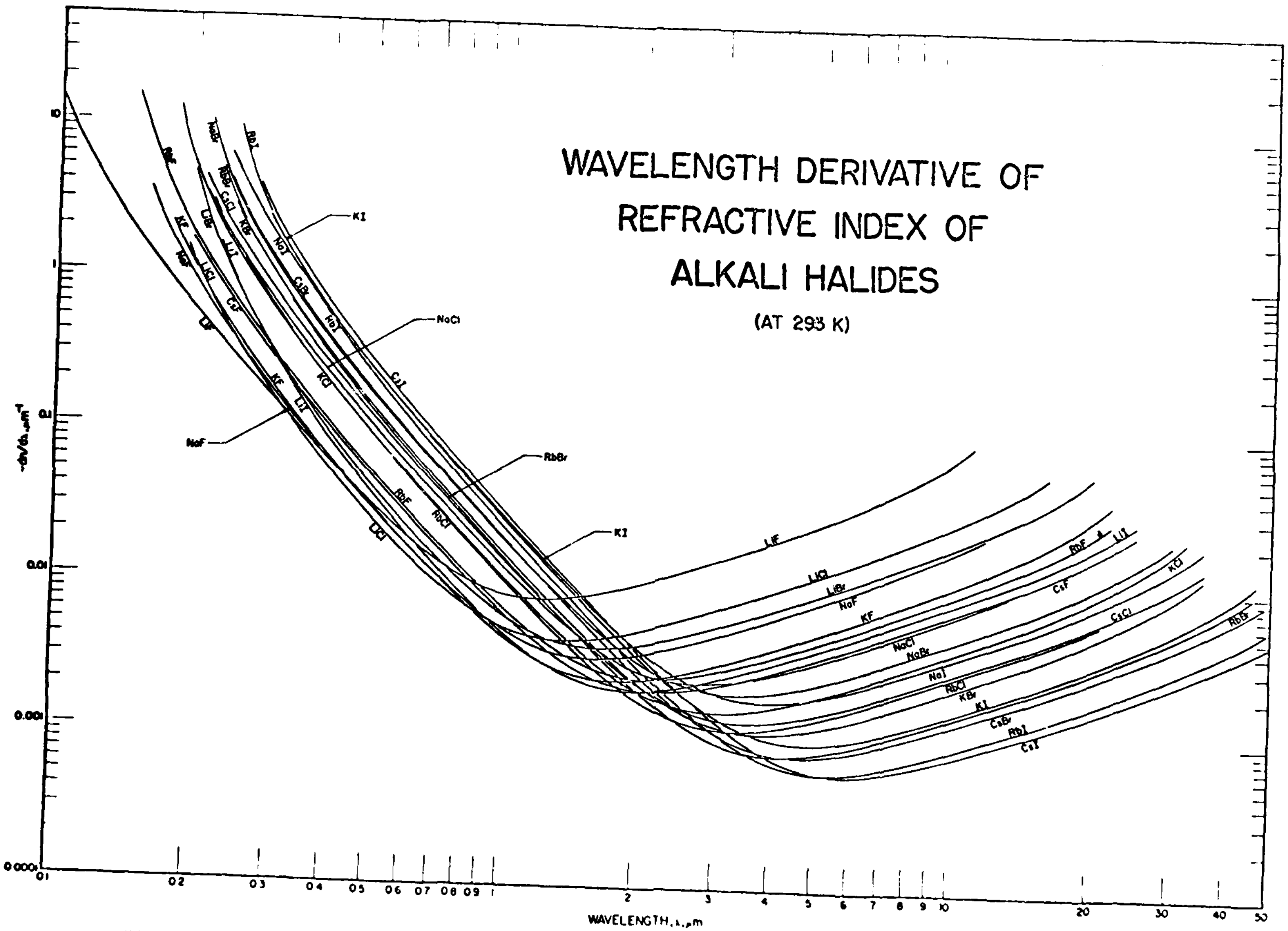

Figure 21. Provisional values for the wavelength derivative of the refractive index of all twenty alkali halides. Most of the values are calculated.

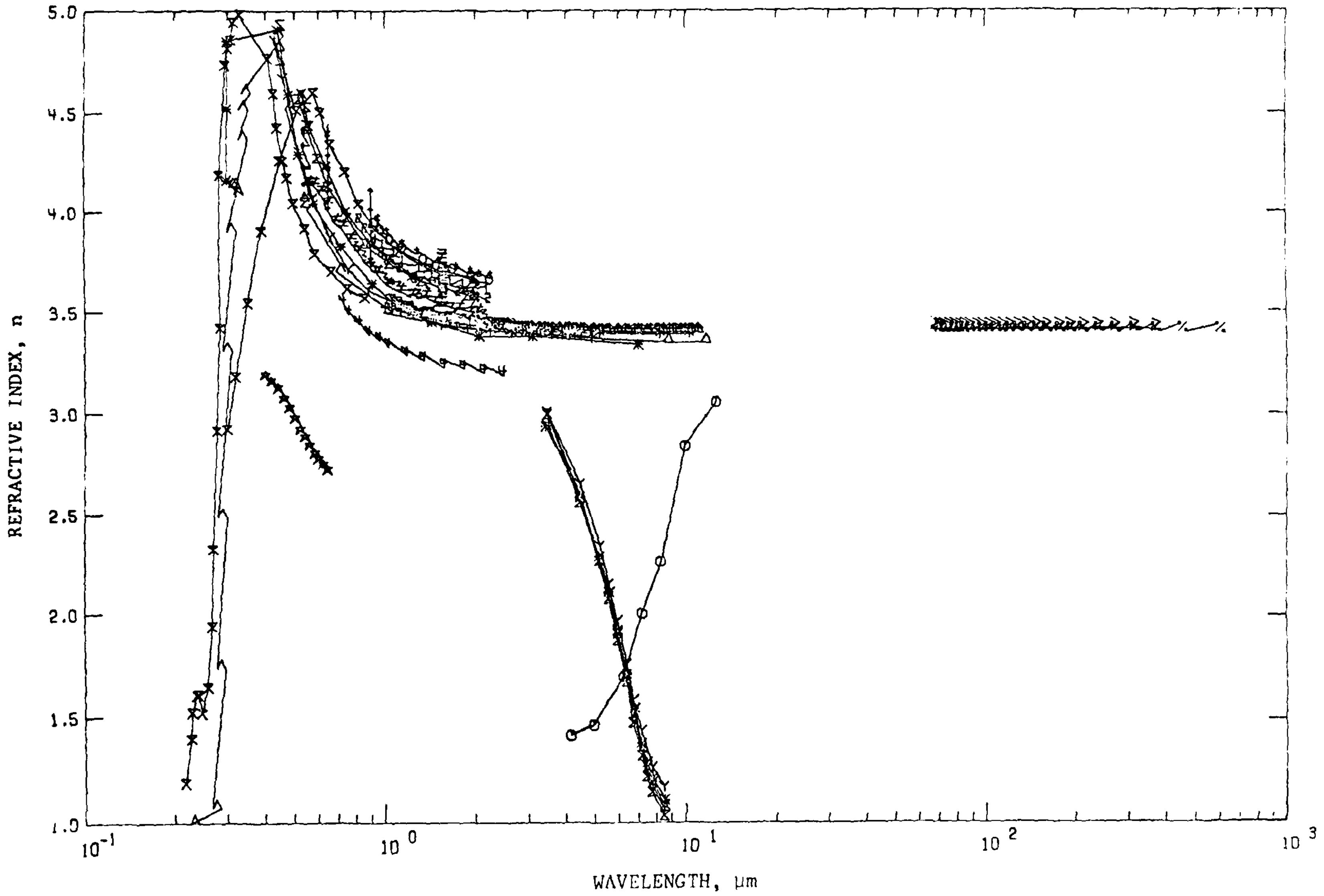

Figure 22. Experimental data on the refractive index of silicon (wavelength dependence).

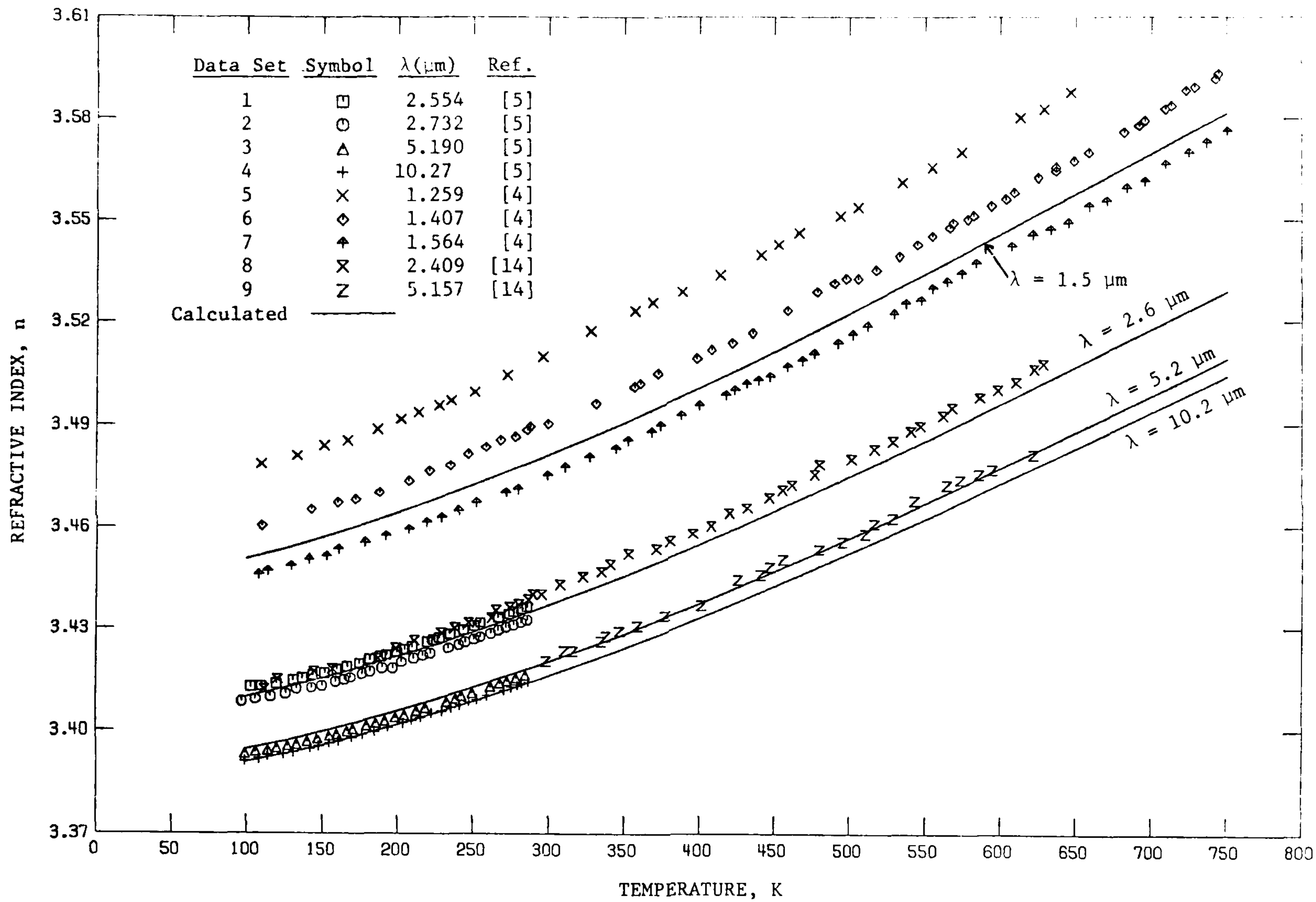

Figure 23. Experimental data on the refractive index of silicon (temperature dependence). Some calculated values are also shown for comparison.

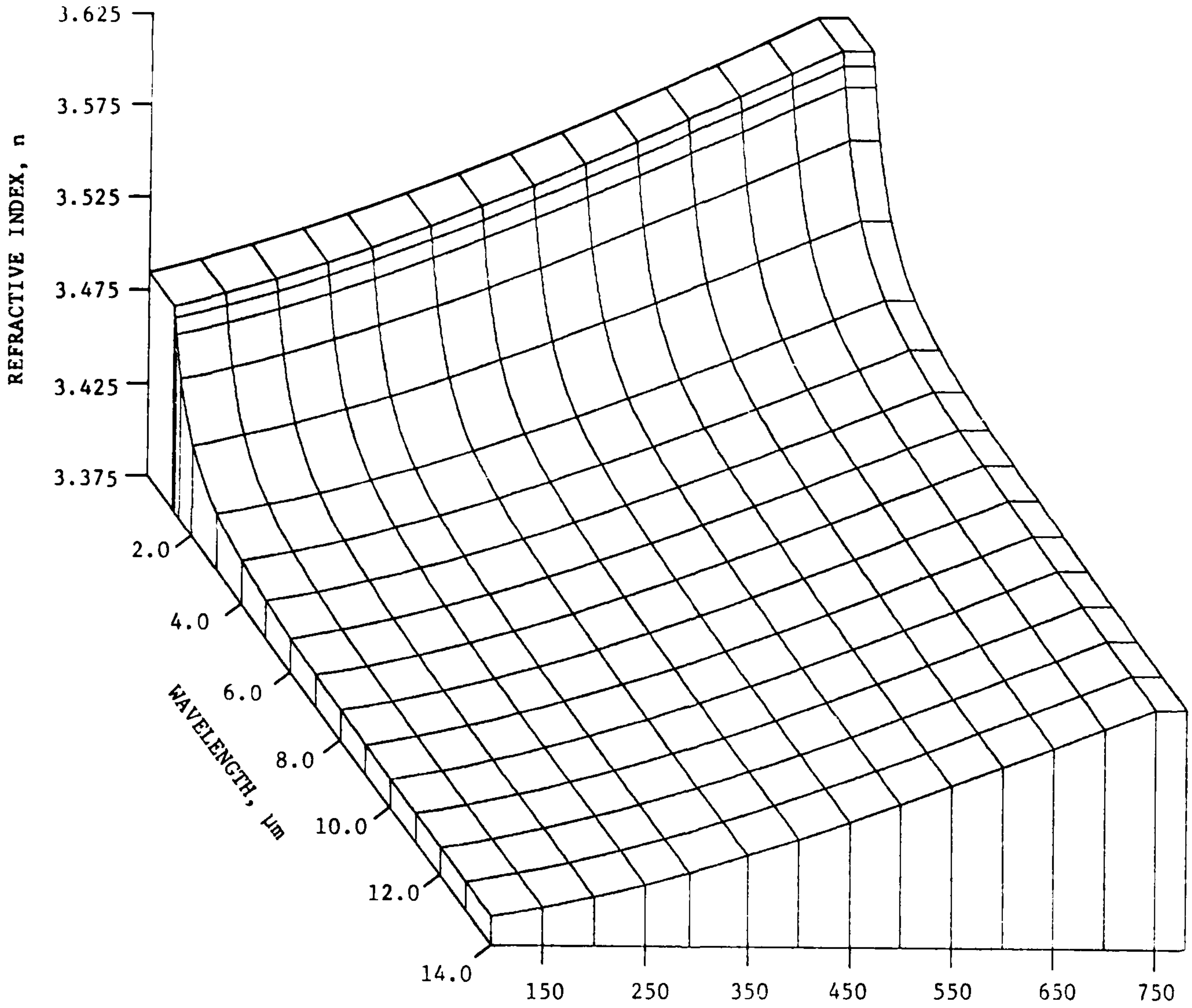

Figure 24. Recommended values for the refractive index of silicon as a function of both wavelength and temperature.

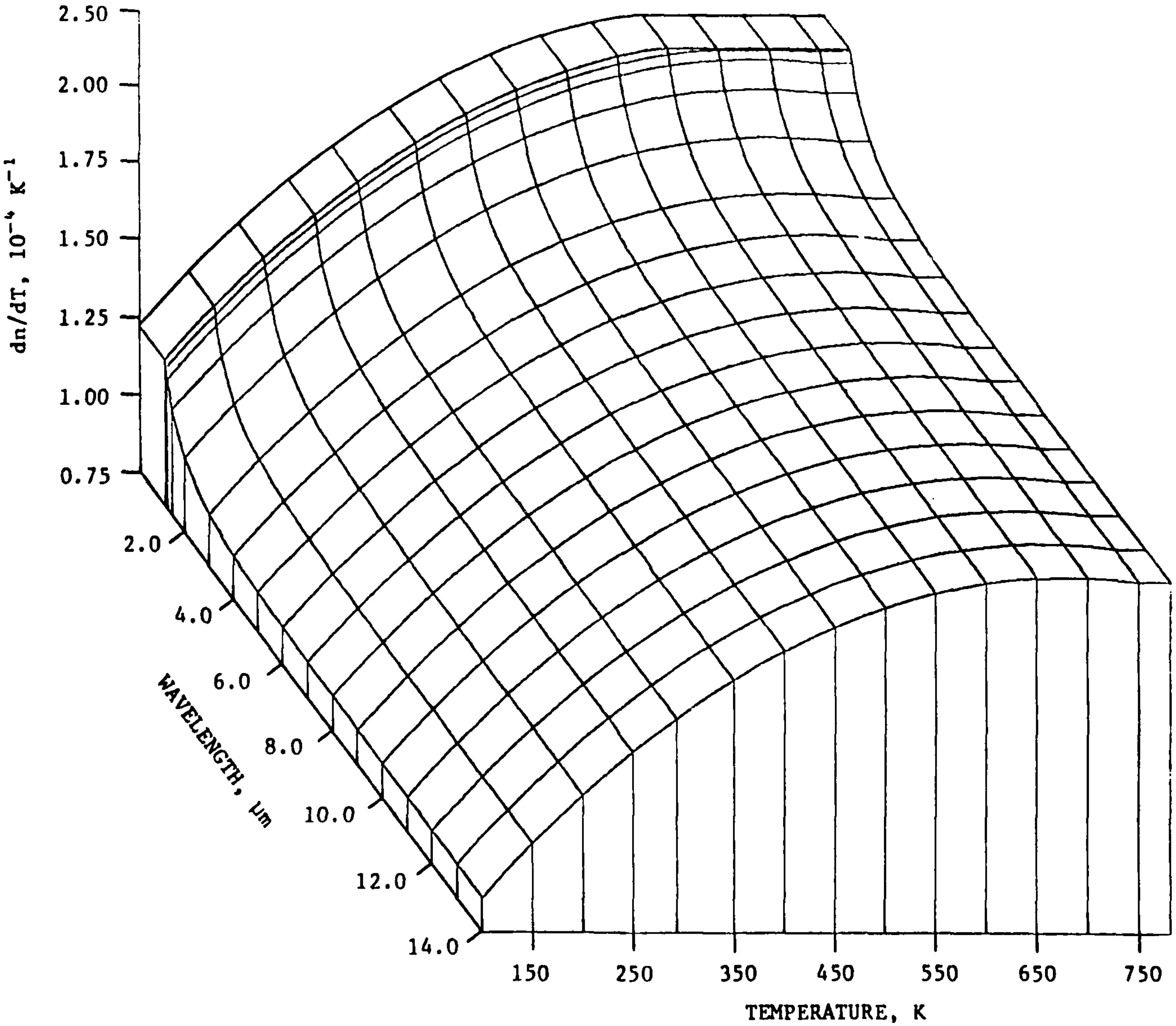

Figure 25. Recommended values for the temperature derivative of the refractive index of silicon as a function of both wavelength and temperature.

3. HANDBOOKS AND DATA BOOKS[a]

The phenomenal growth of science and technology in recent decades has brought about a universal appreciation of the fact that the availability of adequate reference data for various properties of materials is essential to national progress, economy, and defense. To this end, TEPIAC has been contributing greatly through the generation of reference data tables and the design, preparation, publication, and maintenance of data books and handbooks, which is the principal means of satisfying user requirements for comprehensive and authoritative data and information on material properties.

The monumental 14-volume 16,810-page Thermophysical Properties of Matter - The TPRC Data Series has been completed and a summary of statistical data on the entire Data Series is presented in Table 11. As the TPRC Data Series is completed, a new plan for the continuing data tables generation and publication with an even greater scope has been developed and is being implemented. In this paln, a new 42-volume McGraw-Hill/CINDAS Data Series on Material Properties will be prepared and published within a time frame of 10-15 years. The structure of the new CINDAS Data Series had been revised three times from the initial conceptual presentation of it in 1977 to late 1979. In early 1980 a realistic structure was attained and it was contemplated that the new CINDAS Data Series would consist of some 42 volumes comprising approximately 14,000 pages. The revised structure and scope of the CINDAS Data Series is presented in Table 12. The revision of the structuring of the CINDAS Data Series had been mainly the combination of volumes conceived earlier. For example, the earlier conceived two volumes: one on "Nonstainless Alloy Steels" and the other on "Carbon Steels and Cast Irons" is combined to become a larger volume entitled "Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons"; the completion of this volume will actually be the completion of two volumes on alloys. The earlier conceived volume on "Alloys of Hafnium, Molybdenum, Niobium, Tantalum, Titanium, Tungsten, and Zirconium" is combined with three other volumes on alloys to become a much larger volume entitled "Properties of Selected Transition-Metal Alloys," the completion of which will actually be the completion of four volumes on alloys.

Volumes in the new CINDAS Data Series are primarily application (material) oriented, in contrast to the discipline (property) oriented structure of the

[a] The work on handbooks and data books has been jointly sponsored by DLA and other agencies and organizations.

TABLE 11. SUMMARY OF STATISTICAL DATA ON "THERMOPHYSICAL PROPERTIES OF MATTER - THE TPRC DATA SERIES"

	No. of Pages	No. of Data Sets	No. of Materials	No. of References: To Text	No. of References: To Data Sources	No. of References: Total
Volume 1. Thermal Conductivity - Metallic Elements and Alloys	1595	5539	892	433	1013	1446
Volume 2. Thermal Conductivity - Nonmetallic Solids	1302	4627	812	439	598	1037
Volume 3. Thermal Conductivity - Nonmetallic Liquids and Gases	707	1505	170	681	725	1406
Volume 4. Specific Heat - Metallic Elements and Alloys	830	1186	322	61	428	789
Volume 5. Specific Heat - Nonmetallic Solids	1737	1009	550	61	457	518
Volume 6. Specific Heat - Nonmetallic Liquids and Gases	383	863	56	70	595	665
Volume 6 Supplement	169	726	307	0	878	878
Volume 7. Thermal Radiative Properties - Metallic Elements and Alloys	1644	5130	242	149	371	520
Volume 8. Thermal Radiative Properties - Nonmetallic Solids	1890	4971	782	121	455	576
Volume 9. Thermal Radiative Properties - Coatings	1569	5269	1161	180	295	475
Volume 10. Thermal Diffusivity	760	1733	445	253	315	568
Volume 11. Viscosity	801	1803	188	1218	377	1595
Volume 12. Thermal Expansion - Metallic Elements and Alloys	1440	4253	672	91	781	872
Volume 13. Thermal Expansion - Nonmetallic Solids	1786	4990	815	101	1112	1213
Index Volume. Master Index to Materials and Properties	197	----	6362	---	----	----
Total	16810	43604	----	3858	8400	12258

TABLE 12. STRUCTURE AND SCOPE OF "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"

GROUP I. THEORY, ESTIMATION, AND MEASUREMENT OF PROPERTIES

Volume I-1. Transport Properties of Fluids: Thermal Conductivity, Viscosity, and Diffusion Coefficient
Volume I-2. Transport Properties of Solids: Thermal Conductivity, Electrical Resistivity, and Thermoelectric Properties
Volume I-3. Specific Heat of Solids
Volume I-4. Thermal Expansion of Solids
Volume I-5. Thermal Radiative Properties of Solids

GROUP II. PROPERTIES OF SPECIAL MATERIALS

Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases
Volume II-2. Physical Properties of Rocks and Minerals
Volume II-3. Optical Properties of Optical Materials
Volume II-4. Thermal Radiative Properties of Coatings

GROUP III. PROPERTIES OF THE ELEMENTS

Volume III-1. Properties of Selected Ferrous Alloying Elements (Cr, Co, Fe, Mn, Ni, and V)
Volume III-2. Properties of Nonmetallic Fluid Elements (Ar, Br, Cl, F, He, H_2, I, Kr, Ne, N_2, O_2, Rn, and Xe)
Volume III-3. Properties of Selected Refractory Elements (Hf, Mo, Nb, Ta, Ti, W, and Zr)
Volume III-4. Properties of Liquid Metal Elements (Li, Na, K, Rb, Cs, Fr, Hg, Ga, and In)
Volume III-5. Properties of Selected Nonferrous Alloying Elements and Precious Metals (Al, Be, Cd, Cu, Pb, Mg, Sn, Zn, Au, Ir, Pd, Pt, Re, Rh, and Ag)
Volume III-6. Properties of Rare-Earth and Radioactive Elements (Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Tc, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, and Lw)
Volume III-7. Properties of Selected Semiconducting, Semimetallic, Nonmetallic Solid, and Other Elements (Ge, Po, Se, Si, Te, Sb, As, Bi, At, B, C, P, S, Ba, Ca, Os, Ru, Sr, and Tl)

GROUP IV. PROPERTIES OF ALLOYS AND CERMETS

Volume IV-1. Properties of Stainless Steels
Volume IV-2. Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons
Volume IV-3. Properties of Selected Transition-Metal Alloys (Alloys of Cr, Co, Hf, Mn, Mo, Ni, Nb, Pd, Pt, Rh, Ta, Ti, W, U, V, and Zr)
Volume IV-4. Properties of Selected Nontransition-Metal Alloys (Alloys of Al, Sb, Be, Bi, Cd, In, Pb, Mg, Sn, and Zn)
Volume IV-5. Properties of Copper Alloys, Gold Alloys, and Silver Alloys
Volume IV-6. Properties of Cermets

GROUP V. PROPERTIES OF FLUIDS AND FLUID MIXTURES

Volume V-1. Properties of Inorganic and Organic Fluids
Volume V-2. Properties of Commercial Refrigerants and Fluid Mixtures

GROUP VI. PROPERTIES OF OXIDES AND OXIDE MIXTURES

Volume VI-1. Properties of Rare-Earth Oxides and Actinide Oxides
(Oxides of Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ac, Th, Pa, U, Np, Pu, and Am)
Volume VI-2. Properties of Electronic Oxides
(Oxides of Cr, Co, Cu, Fe, Mn, Ni, Ti, V, and Zn)
Volume VI-3. Properties of Selected Nontransition-Metal Oxides
(Oxides of Al, Sb, Ba, Be, Bi, Cd, Ca, Cs, Fr, Ga, Ge, Au, In, Pb, Li, Mg, Hg, Po, K, Ra, Rb, Ag, Na, Sr, Tl, and Sn)
Volume VI-4. Properties of Selected Transition-Metal Oxides and Oxides of Selected Nonmetallic Solid Elements
(Oxides of Hf, Ir, Mo, Nb, Os, Pd, Pt, Re, Rh, Ru, Ta, Tc, W, Zr, As, B, P, Se, Si, and Te)
Volume VI-5. Properties of Complex Oxides
Volume VI-6. Properties of Oxide Mixtures
Volume VI-7. Properties of Ceramics and Glasses

GROUP VII. PROPERTIES OF COMMERCIAL GRAPHITES, COMPOSITES, AND SYSTEMS

Volume VII-1. Properties of Commercial Graphites and Carbon-Carbon Composites
Volume VII-2. Properties of Composites
(Other than Carbon-Carbon Composites)
Volume VII-3. Properties of Systems

GROUP VIII. PROPERTIES OF NON-OXIDE INORGANIC COMPOUNDS AND INTERMETALLIC COMPOUNDS

Volume VIII-1. Properties of Halides
(Bromides, Chlorides, Fluorides, and Iodides)
Volume VIII-2. Properties of Borides, Carbides, Hydrides, Nitrides, and Silicides
Volume VIII-3. Properties of Arsenides, Phosphides, Selenides, Sulfides, and Tellurides
Volume VIII-4. Properties of Carbonates, Nitrates, Phosphates, Silicates, and Sulfates
Volume VIII-5. Properties of Intermetallic Compounds

GROUP IX. PROPERTIES OF POLYMERS, ORGANIC COMPOUNDS, FOODS, BIOLOGICAL MATERIALS, AND BUILDING MATERIALS

Volume IX-1. Properties of Polymers
Volume IX-2. Properties of Organic Compounds, Foods, and Biological Materials
Volume IX-3. Properties of Building Materials

old TPRC Data Series. In other words, each volume in the CINDAS Data Series contains data on all the important physical properties of a group of materials, rather than containing data on only one property of many materials such as the volume in the old TPRC Data Series. In presenting the property data in each volume, all possible steps are taken to reduce the buck of the presentation by limiting the reporting to essential elements of information without sacrificing the information essential for scientific and technical usage of the data reported. In other words, the volumes comprise mainly the recommended reference values or selected important data.

Table 13 shows the properties covered by the volumes of the new CINDAS Data Series. The properties include eleven thermophysical and seven electrical, electronic, optical, and magnetic properties which are to be presented as a function of one or more variables such as temperature, pressure, wavelength, etc. and further include twelve additional thermophysical properties, four additional electrical and electronic properties, and fifteen mechanical properties which are given for room temperature or as single values. It is important to note that the properties covered include not only all the important thermophysical, electronic, electrical, magnetic, and optical properties but also all the important room-temperature mechanical properties. Although mechanical properties are outside the scope of TEPIAC, it is believed that the inclusion of a large number of mechanical properties (even with values given for room temperature only) would increase the usefulness of the volumes significantly.

The following four volumes of the new McGraw-Hill/CINDAS Data Series have recently been published:

Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases
Volume II-2. Physical Properties of Rocks and Minerals
Volume III-1. Properties of Selected Ferrous Alloying Elements
Volume III-2. Properties of Nonmetallic Fluid Elements.

Volume II-1 has 448 pages (xxxvi + 412) and contains 162 tables, 26 figures, and 1182 references (655 references to text on thermal accommodation coefficient, 206 references to data on thermal accommodation coefficient, and 321 references to gas adsorption). In addition to giving a most comprehensive review and discussion of the theories, methods of measurement, and methods of calculation

TABLE 13. PROPERTIES COVERED BY "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"[a]

I. PROPERTIES PRESENTED AS A FUNCTION OF ONE OR MORE VARIABLES

A. Thermophysical Properties

1. Thermal Conductivity
2. Specific heat
3. Thermal linear expansion
4. Thermal diffusivity
5. Thermal emittance
6. Thermal reflectance
7. Thermal absorptance
8. Thermal transmittance
9. Solar absorptance to emittance ratio
10. Viscosity
11. Prandtl number[b]

B. Electrical, Electronic, Optical, and Magnetic Properties

12. Electrical resistivity
13. Thermoelectric power
14. Dielectric constant[c]
15. Hall coefficient
16. Optical constants (absorption index and refractive index)
17. Magnetic susceptibility

II. PROPERTIES PRESENTED AS A SINGLE VALUE OR FOR ROOM TEMPERATURE

A. Thermophysical Properties

18. Density (at NTP)
19. Normal melting point
20. Normal boiling point
21. Triple point
22. Critical temperature and pressure
23. Phase transition temperature
24. Magnetic transition temperature
25. Superconducting transition temperature
26. Debye temperature (at T)
27. Heat of fusion (at NMP)
28. Heat of vaporization (at NBP)
29. Vapor pressure (at T)

B. Electrical and Electronic Properties

30. Dielectric strength
31. Mobility
32. Energy gap
33. Work function

C. Mechanical Properties

34. Elastic constants (c_{ij})
35. Tensile strength
36. Yield strength
37. Compressive strength
38. Shear strength
39. Impact strength
40. Young's modulus
41. Compressive modulus
42. Shear modulus
43. Bulk modulus
44. Poisson's ratio
45. Hardness
46. Toughness
47. Creep rate
48. Velocity of sound (longitudinal and transverse)

[a] Data on some of the properties are presented only for selected materials.
[b] Presented only for materials which are fluid at NTP.
[c] Presented only for long wavelengths ($\lambda > 100$ μm).

and prediction of the thermal accommodation coefficient and of the gas adsorption, this volume presents 591 sets of experimental data on the thermal accommodation coefficient of 159 solid-gas systems and presents or describes 288 sets of experimental results on the gas adsorption of 36 solid-gas systems.

Volume II-2 has 568 pages (xx + 548) and contains 77 tables, 266 figures, and 1797 references (1111 cited references and 686 references listed in appendices). It covers 29 thermal, electrical, magnetic, physical, and mechanical properties and 116 types of rocks and 222 minerals. In addition to properties of rocks and minerals, this volume contains information and data also on the constitution of rocks and on the heat flow from the earth crust of the United States.

Volume III-1 has 285 pages (xvi + 269) and contains 91 tables, 107 figures, and 1736 references. It presents data and information on 43 properties of six selected ferrous alloying elements, which are: chromium, cobalt, iron, manganese, nickel, and vanadium. The 43 properties include 13 major properties which are presented as a function of one or more variables and 30 other properties which are given as a single value or for room temperature.

Volume III-2 has 224 pages (xvi + 208) and contains 138 tables, 72 figures, and 269 references. It presents data and information on 15 properties of 19 nonmetallic fluid elements and isotopes, which are: argon, bromine, chlorine, deuterium, fluorine, helium-3, helium-4, normal hydrogen, ortho-hydrogen, para-hydrogen, iodine, krypton, neon, nitrogen, oxygen, ozone, radon, tritium, and xenon. The 15 properties include four major properties which are presented as a function of one or more variables and 11 others given as a single value or for room temperature.

The tables of contents of the four published volumes of the new McGraw-Hill/CINDAS Data Series reported above are given in Appendix 1 to show the scope of their coverage. Table 14 presents a summary of statistical data on these four published volumes.

Currently we are working on the following two additional volumes of the McGraw-Hill/CINDAS Data Series:

Volume IV-1. Properties of Stainless Steels

Volume V-1. Properties of Inorganic and Organic Fluids

The preparation of manuscripts for these two volumes has been in full progress.

TABLE 14. SUMMARY OF STATISTICAL DATA ON THE PUBLISHED VOLUMES OF "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"

	No. of Pages	No. of Materials	No. of Properties	No. of Tables	No. of Figures	No. of References
Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases	448	195	2	162	26	1,182
Volume II-2. Physical Properties of Rocks and Minerals	568	338	29	77	266	1,797
Volume III-1. Properties of Selected Ferrous Alloying Elements	285	6	43	91	107	1,736
Volume III-2. Properties of Nonmetallic Fluid Elements	224	19	15	138	72	269
	1,525	558	--	468	471	4,984

Volume IV-1 covers the U.S. stainless steels and will contain the property data and information on about 37 AISI stainless steels and 35 other U.S. stainless steels without AISI designations, and will have about 450 pages. The 37 AISI stainless steels to be covered are AISI 201, AISI 202, AISI 301, AISI 302, AISI 303, AISI 304, AISI 305, AISI 308, AISI 309, AISI 310, AISI 314, AISI 316, AISI 317, AISI 321, AISI 330, AISI 347, AISI 348, AISI 403, AISI 405, AISI 406, AISI 410, AISI 416, AISI 420, AISI 429, AISI 430, AISI 431, AISI 440C, AISI 446, AISI 630 (17-4PH), AISI 631 (17-7PH), AISI 632 (PH15-7Mo), AISI 633 (AM 350), AISI 634 (AM 355), AISI 635 (Stainless W), AISI 651 (19-9DL), AISI 660 (A-286), and AISI 661 (N-155).

Volume V-1 will contain the property data and information on 28 inorganic and organic compounds in liquid and gaseous states. These compounds are acetone, acetylene, ammonia, benzene, boron trifluoride, carbon monoxide, chloroform, n-decane, ethyl alcohol, ethyl ether, ethylene glycol, glycerol, n-heptane, n-hexane, hydrogen chloride, hydrogen iodide, hydrogen sulfide, methane, methyl alcohol, nitric oxide, nitrogen peroxide, nitrous oxide, n-nonane, n-octane, n-pentane, sulfur dioxide, toluene, and water.

In the meantime the works on the following seven volumes of the McGraw-Hill/CINDAS Data Series have been initiated:

- Volume I-1. Transport Properties of Fluids: Thermal Conductivity, Viscosity, and Diffusion Coefficient
- Volume I-2. Transport Properties of Solids: Thermal Conductivity, Electrical Resistivity, and Thermoelectric Properties
- Volume I-3. Specific Heat of Solids
- Volume I-4. Thermal Expansion of Solids
- Volume I-5. Thermal Radiative Properties of Solids
- Volume VI-1. Properties of Rare-Earth Oxides and Actinide Oxides
- Volume II-3. Optical Properties of Optical Materials

The technical works for the first six of the seven volumes listed above are being contributed by scientists outside CINDAS.

During the visit of Mr. J.F. Pendergast (the new IAC Program Manager) and Mr. Samuel Valencia (the former COTR) to CINDAS on 5 August 1980 to review TEPIAC's operations and programs, priority volumes to be selected for future work were proposed and discussed, among other topics. It was approved by

Mr. Pendergast and Mr. Valencia that, when Volumes IV-1 and V-1 are completed, we will proceed to work on the following three volumes:

Volume IV-2. Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons

Volume V-2. Properties of Commercial Refrigerants and Fluid Mixtures

Volume III-3. Properties of Selected Refractory Elements

As discussed previously, Volume IV-2 is actually the combination of two volumes on alloys conceived earlier.

4. STATE-OF-THE-ART REPORTS, CRITICAL REVIEWS, AND TECHNOLOGY ASSESSMENTS

In order to keep abreast of the user needs in relation to high-interest technology and information, TEPIAC has prepared and issued state-of-the-art reports, critical reviews, and technology assessments, which are special technical reports resulted, respectively, from comprehensive studies, extensive critical reviews, and short comparative assessments of current high-interest technology and information.

In this 12-month reporting period two major technical reports were completed, which are as follows:

(1) "English Translation of Seven Papers on Thermophysical Properties," Purdue University, CINDAS Report 58, 79 pp., 1980.

This report contains the F ..lish translations of one French and six Russian papers with the following titles:

(1) Reflectivity and emissivity coefficients of UO_2 at high temperatures.
(2) Influence of modifiers on the properties and structures of cast iron in light of the electron theory of metals.
(3) Viscosity of Freon 21, Freon 22, and Freon 23.
(4) Study of the magnetic state phase diagram of the chromium sulfide telluride (CrS_xTe_{1-x}) quasibinary system.
(5) Density of molten metals and its temperature dependence.
(6) Low-temperature characteristics of the Wiedemann-Franz law in aging alloys.
(7) Relation of the thermophysical properties of low-alloy steels to temperature.

(2) "How to Evaluate and Synthesize Literature Data on Physical Propertie.," Purdue University, CINDAS Special Report, 65 pp., 1980.

This report describes and discusses the methodology of critical evaluation, correlation, analysis, and synthesis of physical properties data used at TEPIAC/CINDAS and shows how the fragmentary and conflicting

experimental data recorded in the scientific and technical literature can be thoroughly evaluated, analyzed, correlated, and synthesized to generate a full field of information hitherto unavailable. It demonstrates with practical examples covering thermal transport, thermodynamic, thermal radiative, electrical, thermoelectric, and optical properties of various solid materials that data evaluation, correlation, analysis, and synthesis is a very powerful tool that not only can bring order out of conflicting, confusing, and chaotic experimental observations and come up with correct values, but also can create new data and new knowledge, which in itself is a major contribution to science and technology. It is shown further that critically evaluated, recommended reference data are generated at a tiny fraction of the cost and time required for producing the original experimental raw data, and that data critique must be considered an integral part of research if research results are to be meaningful and useful. The report conveys the important message that TEPIAC/CINDAS can provide to the user not just the available data and information from the literature (which is usually the limit that an ordinary information center can do), but the evaluated correct data and information, and furthermore, in many cases TEPIAC/CINDAS can also provide predicted data and information even when the required data and information are completely lacking and nonexisting.

One of the technical reports prepared previously for AMMRC and DLA has been published in this year as a formal publication in a well-known scientific and technical journal. This formal publication is:

"Refractive Index of Silicon and Germanium and Its Wavelength and Temperature Derivatives," Journal of Physical and Chemical Reference Data, 9(3), 561-658, 1980. [Originally this is CINDAS Report 53]

5. CARBON-CARBON COMPOSITES DATA BANK

The primary objective of this special project is to develop and establish a numerical data bank on the physical properties of carbon-carbon composites. This project is conducted in conjunction with MCIC/Battelle and the carbon-carbon composites are limited to a number of selected specific types. The responsibility of TEPIAC in this project is to cover the following five thermophysical properties:

(1) Thermal conductivity

(2) Specific heat

(3) Thermal expansion

(4) Thermal diffusivity

(5) Thermal radiative properties.

In addition to the data on specific types of carbon-carbon composites, data on carbon felt-type insulations are also of interest to this project.

As data on selected types of carbon-carbon composites and carbon-composite thermal insulators are accepted for entry into the carbon-carbon composites data bank, they are extracted following the comprehensive list of "Thermophysical Property Data Extraction Parameters," which was developed previously at TEPIAC and subsequently incorporated into the computer file structure of the data bank. At the end of 1980 a total of 464 data sets have been forwarded to MCIC/Battelle to enter into the carbon-carbon composites data bank: 97 data sets for thermal conductivity, 364 for thermal linear expansion, and 3 for specific heat. An additional 50 data sets for thermal expansion are presently being keyboarded. Overall, a total of 83 carbon-carbon composite materials are represented.

A secondary objective of this project, and one which TEPIAC is taking part in, is the critical evaluation of thermophysical property data on carbon-carbon composites. Of current interest is the following situation. Coarse-weave carbon-carbon composites have unit cells of such a size that a test specimen cross-section may encompass only a few unit cells within its boundaries. A study is being undertaken to examine aspects of this problem upon thermal diffusivity measurement. TEPIAC is presently conducting a geometrical study of the fiber-bundle fraction parameter for a coarse-weave structure which is viewed by means of a circular aperture as is done, for instance, in the thermal diffusivity flash technique. A report on the findings of this study, entitled "Coarse Weave Carbon-Carbon Composite: A Viewing Spot Size Problem Occurring for Thermal Diffusivity Specimen," is presently being reviewed for publication in MCIC's Current Awareness Bulletin. Our findings also were reported at the Second Carbon-Carbon Nozzle Technology Conference, held at Monterey, California, October 22-23, 1980. The work is being continued to see what limits are imposed upon the correlation of fiber fraction to thermal diffusivity.

An evaluation of existing data on the specific heat of POCO graphite and of 3D carbon-carbon composites is being carried out to determine the applicability of the POCO data for the conversion of thermal diffusivity data on carbon-carbon composites to thermal conductivity values. A preliminary report on this is in preparation.

6. COMPUTERIZED NUMERICAL DATA STORAGE AND RETRIEVAL SYSTEM

Although TEPIAC has possessed a fully computerized bibliographic information storage and retrieval system capable of instant retrieval of all kinds of

bibliographic information, the computerized numerical data storage and retrieval system is still under development.

This computerized numerical data storage and retrieval system will comprise two data files (data banks): one on evaluated numerical data (recommended values) and the other on unevaluated numerical data (raw experimental data).

For the evaluated numerical data bank, the overall design of the data bank and of the data capturing scheme had long been completed and the computer programming for storing the data has been finished. However, much remains to be done, especially in the computer programming phase of data retrieval and manipulation. Evaluated data extracted from seventeen data source references have been stored on magnetic tapes in this data bank, which currently contains 4,268 evaluated data sets (comprising 69,439 data points) on 15 properties of 1,764 materials. For the unevaluated numerical data bank no work has yet been done.

This computerized numerical data system, when completed, should eventually be able to perform at least the following functions:

(1) Store and retrieve recommended reference data together with information on material identification and characterization and on data uncertainty.

(2) Store and retrieve experimental data together with information on specimen specification and characterization and on measurement method and condition.

(3) Manipulate data for data analysis, correlation, derivation, curve fitting, etc.

(4) Prepare tables, graphs, and list of references by computer for publication and for answering technical inquiries.

(5) Search for materials with given ranges of values of various properties.

(6) Be used for on-line computer search.

SECTION IV

INQUIRY SERVICES

TEPIAC's day-by-day contributions in inquiry services to individual users have been primarily in the nature of specialized advisory and technical consulting, data recommendation and prediction, and special bibliographic and data searches. During this 12-month reporting period 515 inquiries have been responded, of which 430 came from 42 states and the District of Columbia and 85 from 27 foreign countries. It is noted also that 64 of the 515 inquiries came from government laboratories and agencies, 109 from academic institutions, and 342 from defense contractors and other industrial organizations. Detailed statistical summary of inquiry responses for 1980 is presented in Table 15. Table 16 shows the geographical distribution of inquiry responses for 1980. A summary of inquiry responses for the last 18 years since 1963 is presented in Figure 26.

Over the years TEPIAC has developed a most efficient way for responding to technical and bibliographic inquiries. This is the result of our efficient "User Service Control System," which is based on the concept of having one staff member to be responsible for centralized control and coordination of requests and responses and using the contributions from various staff members whose expertises are in the areas of the requests. Furthermore, in order to expedite the service, TEPIAC accepts authorization for requests for normal technical and bibliographic inquiries by telephone as well as by letter or purchase order. All technical inquiry responses are recorded by the serial number, date, analyst (persons contributing to answering query), total hours, subject code, fee charged or service code, user codes, and mailing address. These recorded data are very useful for user service control and are also reported to the sponsor in the Quarterly R & D Contract Status Reports.

In order to assess the usefulness of TEPIAC's inquiry service and the degree of user satisfaction, a short questionnaire is sent to each inquirer together with the inquiry response (see Appendix 2 for a copy of TEPIAC Technical Inquiry Questionnaire). It should be noted that this simple questionnaire can be easily and quickly filled out by simple checks or short answers to questions. The information from the returned questionnaire is used as a feedback to our User Service Control System for constantly improving the quality of TEPIAC's inquiry service.

TABLE 15. STATISTICAL SUMMARY OF INQUIRY RESPONSES FOR 1980

	Information Request	Publication Request	Technical Question[a]	Bibliographic Search	TOTAL
DOMESTIC					
Government	22	7	8	8	45
Industry	147	53	65	47	312
University	38	8	14	13	73
Subtotal	207	68	87	68	430
FOREIGN					
Government	11	3	3	2	19
Industry	19	6	4	1	30
University	10	18	4	4	36
Subtotal	40	27	11	7	85
TOTAL	247	95	98	75	515

[a] Including data analysis and technical review.

Between 1 July 1977 and 31 December 1980, 1796 questionnaires were mailed out with our responses to inquirers. A total of 454 completed questionnaires were returned to TEPIAC. The rate of return was an outstanding 25.3 percent; most survey researchers would consider a 10 percent return to be excellent. The survey results from these returned questionnaires are presented in Appendix 3. It is very encouraging to note from the survey results that 20 percent of the users of TEPIAC technical inquiry services were "repeat customers". Note also that another 27 percent users were aware of TEPIAC through their co-workers, who must have given to them good recommendations about TEPIAC. Most users were pleased with TEPIAC responses to their inquiries, as 54 percent users rated the TEPIAC responses to be "very good," 36 percent users rated the responses to be adequate, while only 10 percent users considered the responses to be of marginal value. About 96 percent of the replies rated the TEPIAC inquiry service as prompt and 93 percent rated the charges reasonable, and only 3 percent considered the charges to be too high and 4 percent considered the charges too low. Perhaps the most important information obtained from these questionnaires was the value of the TEPIAC responses to the users. The survey results indicate that 44 percent of the responses saved the users 5 hours or less (these include

TABLE 16. GEOGRAPHICAL DISTRIBUTION OF INQUIRY RESPONSES FOR 1980

	No. of Inquiries
Alabama	1
Arizona	9
California	67
Colorado	6
Connecticut	16
Delaware	2
District of Columbia	14
Florida	5
Georgia	1
Hawaii	1
Idaho	1
Illinois	16
Indiana	22
Iowa	4
Kentucky	3
Louisiana	1
Maine	1
Maryland	11
Massachusetts	21
Michigan	13
Minnesota	7
Missouri	9
Montana	1
Nevada	3
New Jersey	13
New Hampshire	1
New Mexico	7
New York	32
North Carolina	1
North Dakota	1
Ohio	40
Oklahoma	2
Oregon	1
Pennsylvania	32
Rhode Island	1
South Carolina	2
Tennessee	9
Texas	19
Utah	2
Virginia	20
Washington	8
West Virginia	1
Wisconsin	3
Domestic	430
Foreign Countries	85
TOTAL	515

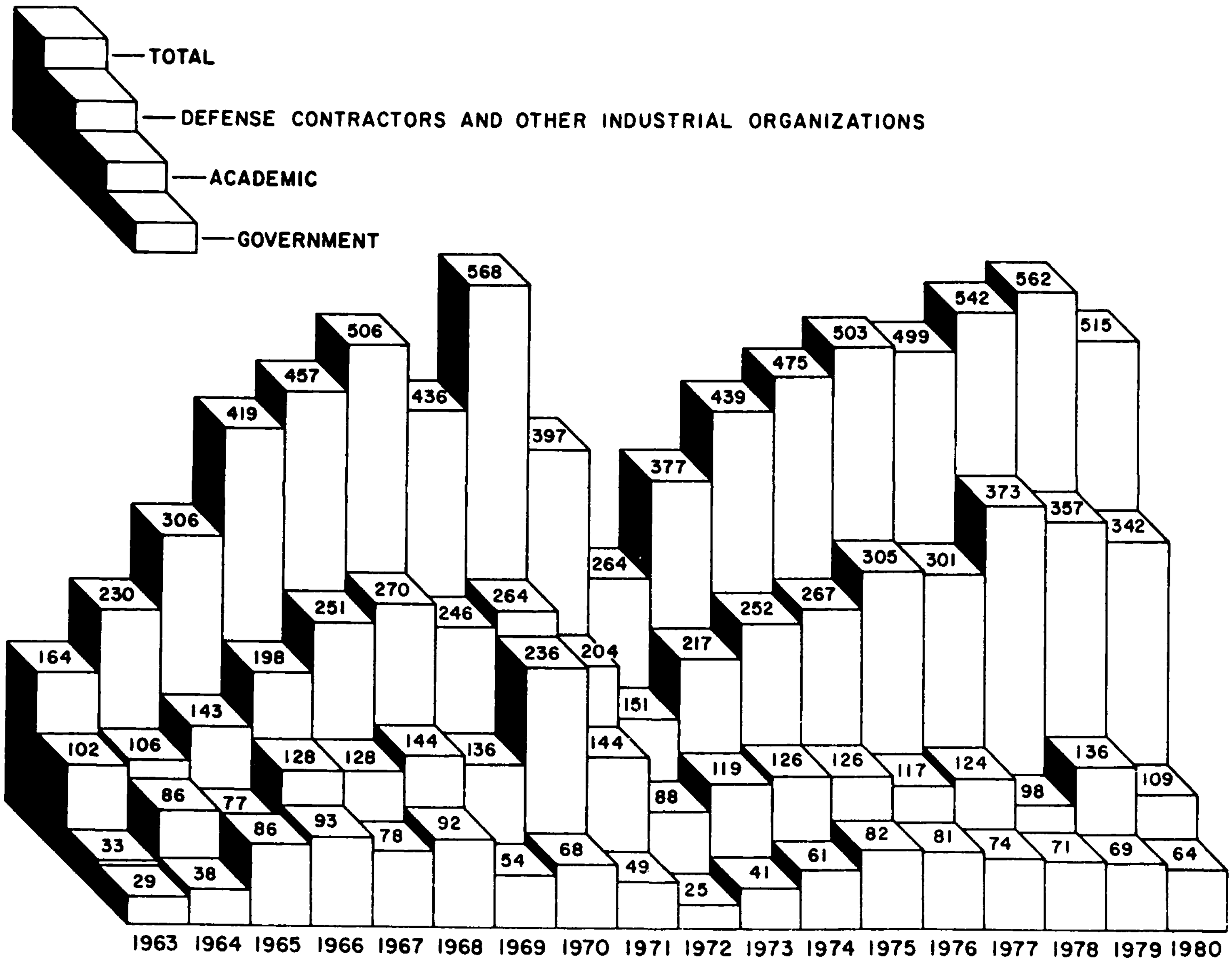

Figure 26. Summary of inquiry responses since 1963.

the responses informing the users that no data/information are uncovered from our exhaustive search for the properties of materials requested), 21 percent of the responses saved the users 40 hours or more, 13 percent of the responses saved the users 20 to 10 hours, another 13 percent saved the users 10 to 5 hours, and 9 percent of the responses saved the users 30 to 20 hours. Those larger savings (far exceeding 40 hours) were from inquiry responses that provided the users with numerical property data rather than bibliographic information. Typical comments of users on TEPIAC inquiry services are also listed in Appendix 3.

It is important to note that even though TEPIAC has provided excellent inquiry services to the users, these services impart only a relatively small portion of the total information and data that TEPIAC has provided to the users. The major portion of the information and data are provided to the users through TEPIAC's major publications. For example, users commented "we are regularly using Volumes 1-13 of the Thermophysical Properties of Matter - The TPRC Data Series; these volumes are extremely useful in our research". Of course, there are countless other unreported cases where users have used the data and information contained in this and other major publications of TEPIAC. Consider the fact that there are 29 volumes of major data books (with a total of 30,486 pages) and 19 volumes of research literature retrieval guides (with a total of 8,258 pages) that have been published by TEPIAC/CINDAS over the years. From about 500 to over 1,000 copies (on the average 750 copies) of each of these volumes have been sold mainly to the libraries of government research and development laboratories, academic institutions, defense contractors, and other industrial organizations. It is believed conservative to assume that each volume is used only once a month by only one of the hundreds or thousands of engineers and scientists in an organization possessing any copy of our publications, who would save 20 hours (at $30 per hour including overhead expense) of his time by obtaining and using the data and information from a volume of TEPIAC/CINDAS' publications instead of generating the same data and information himself; the total savings for the Nation would thus be $259,200,000 per year. This illustrates how great a contribution TEPIAC has made to the Department of Defense and to the United States as a whole.

TEPIAC has been maintaining a sound "Service Charge System" including an auditable detailed file of charges and users, and has been seeking its continual improvement. The nominal charges for TEPIAC products and services are as follows:

1. Bibliographic search. The nominal charge for a single bibliographic search is $40. A single bibliographic search is defined as a search for a maximum of five properties of one material for any temperature range and subject area. In the cases of special search requirements, price quotations are given.

2. Technical consultation, data recommendation, data synthesis and prediction. Minor technical assistance is provided at the rate of $30 per hour. Price quotations are given for extended technical services.

3. Publications. Brochures containing information on the content, availability, price, etc. are sent to requesters for information on major book and report publications. Copies of reprints of journal articles written by TEPIAC staff, if available, are sent to requesters free of charge.

4. Reproductions. The charge for microfiche reproduction is $2.50 per fiche. Hard copy reproduction is charged at $0.35 per page. A $5.00 special handling charge will be added to the total charge for an order under $10.00.

5. Promotional and current awareness products and general information on TEPIAC. These are provided at no cost.

Most routine users of scientific and technical information generally order and pay for TEPIAC's products and services through their local technical library or through their scientific and technical information office. TEPIAC has the following flexible payment options available:

1. Pre-paid account. This payment option allows an organization to deposit funds with TEPIAC/Purdue University. When TEPIAC delivers products or services in response to orders placed by organization's authorized employees, it will deduct the costs from the deposit account. The requester will be informed of the remaining dollar balance each time technical service is provided.

2. Telephone/letter authorization, pay later. A user may grant approval by telephone or letter for the performance of services for a specified nominal dollar value. TEPIAC provides the technical services to the

requester, and Purdue University issues an invoice soon after, making reference to the purchase order number, if available, or to the authorization call or letter and the name of authorizing individual.

3. Standing order. This plan authorizes an organization to expend a specified amount of funds by anyone from the organization or by specified personnel only over a specified period. As products and services are rendered, TEPIAC invoices the organization through Purdue University against this established standing order.

4. Blanket purchase agreement (BPA) or military deposit account. DOD agencies use this arrangement with a DD Form 1155 (order for supplies and services). A BPA according to the Armed Services Procurement Regulations (ASPR) is a "simplified method of filling anticipated repetitive needs for small quantities of supplies or services by establishing 'charge accounts' with qualified sources of supply. Blanket purchase agreements are designed to reduce administrative costs in accomplishing small purchases by eliminating the need for issuing individual purchase documents." In addition, BPA's allow for timely fulfillment of order.

It is interesting and informative to note those properties and materials on which information is most frequently requested by inquirers. Therefore, a study of the interest profile of all the technical inquiries in the 48-month period from 1 January 1977 to 31 December 1980 has been made and the findings are presented in Table 17. It can be observed from Table 17 that over 65% of the inquiries were on the top five of the 36 properties and top four of the material groups listed.

Since most users contacted TEPIAC for data and information via the telephone, TEPIAC has installed a national WATS line (No. 1-800-428-7675) to make it easier for all users to call TEPIAC toll free. TEPIAC has attempted a number of innovations in getting the word out and the WATS line is one of the contributions to establish a better and easier communication.

A list of organizations in the United States using TEPIAC inquiry services in the period 1 October 1975 to 31 December 1980 is given in Appendix 4.

TABLE 17. INTEREST PROFILE OF TECHNICAL INQUIRIES

(For the Period 1 January 1977 to 31 December 1980)

A. Properties (listed in the order of interest)

1. Thermal Conductivity	23.7%	14. Magnetic Susceptibility	0.7%
2. Specific Heat	17.1%	15. Absorption Coefficient	0.7%
3. Thermal Linear Expansion	14.4%	16. Thermoelectric Properties	0.7%
4. Electrical Resistivity	9.3%	17. Magnetic Hysteresis	0.3%
5. Thermal Diffusivity	6.8%	18. Mobility	0.3%
6. Viscosity	5.5%	19. Thermal Volumetric Expansion	0.3%
7. Emittance	4.2%	20. Energy Levels	0.3%
8. Refractive Index	3.9%	21. Thermal Cantact Resistance	0.3%
9. Reflectance	2.7%	22. Energy Bands	0.2%
10. Absorptance	2.7%	23. Energy Gap	0.2%
11. Transmittance	1.9%	24. Work Function	0.1%
12. Dielectric Constant	1.6%	25. Misc. (9 Electrical + 3 Thermo.)	1.3%
13. Dielectric Strength	0.8%		

B. Materials (listed in the order of interest)

1. Inorganic Compounds	26.4%	9. Minerals	4.2%
2. Elements	18.5%	10. Organic Compounds[a]	3.1%
3. Non Ferrous Alloys	11.4%	11. Hydrocarbons	1.2%
4. Ferrous Alloys	9.8%	12. Solutions and Mixtures	0.9%
5. Intermetallics	6.3%	13. Foods	0.6%
6. Composites and Systems	5.4%	14. Cermets	0.5%
7. Polymers	5.2%	15. Coatings	0.4%
8. Glasses, Refractories, etc.	4.6%	16. Miscellaneous	1.5%

[a] Excluding hydrocarbons.

SECTION V

CURRENT AWARENESS AND PROMOTION EFFORTS

The "Thermophysics and Electronics Newsletter" has been issued bimonthly since January 1972 to a circulation list of TEPIAC users and potential users as a means of keeping them abreast of significant developments and coming events, the availability of new information and publications, the initiation of new R & D programs, and of the availability of products and services from TEPIAC. The number of names in the mailing list has been increasing slowly and reached 11,000. In this 12-month period 6 issues of the Newsletter have been released with a total of 66,000 copies distributed.

The development of an enelarged and computerized mailing list for TEPIAC users and potential users has been accomplished. A simple profile code is given to each name on the mailing list so that the computer can generate selective mailing lists from a master file, The new mailing list therefore not only covers a greater percentage of TEPIAC's total audience, but also allows the isolation of selected portions of that audience for specialized mailings, which increases the effectiveness of the mailing and saves much money in dissemination costs.

In order to ensure that TEPIAC users and potential users are aware of the Center, the products and services it offers, and the benefits to be realized through use of the Center, promotional brochures are periodically issued and distributed, in addition to the distribution of the bimonthly Newsletter. In 1980, 1000 copies of a two-page brochure entitled "Technical Assistance and Inquiry Services by TEPIAC" have been produced for distribution to make users and potentail users better acquainted with TEPIAC's functions, capabilities, technical assistance, products, and services. We have produced also 1000 copies of a revised TEPIAC Technical Inquiry Questionnaire. This Questionnaire is for assessing the usefulness of TEPIAC's inquiry service and the degree of user satisfaction. A copy of it is sent to each inquirer together with the inquiry response.

In this 12-month period TEPIAC staff participated in 17 conferences and meetings. A list of these 17 conferences and meetings is given in Table 18.

TABLE 18. CONFERENCES AND MEETINGS PARTICIPATED IN BY TEPIAC STAFF MEMBERS IN THE PERIOD 1 JANUARY TO 31 DECEMBER 1980.

Name	Location	Date
Carbon-Carbon Composites Data Bank Technical Meeting	Biddeford, ME	Jan. 24, 1980
1980 JANNAF Propulsion Meeting	Monterey, CA	Mar. 11-13, 1980
JANNAF Rocket Nozzle Technology Subcommittee Meeting on Defects in Carbon-Carbon Composites	Monterey, CA	Mar. 14, 1980
Meeting on Low Risk Carbon-Carbon Exit Cone Construction Program	Beavercreek, OH	Mar. 27-28, 1980
Carbon-Carbon Composites Data Bank Technical Information/ Technical Discussion Meeting	Biddeford, ME Wilmington, MA	Apr. 9, 1980 Apr. 10, 1980
Topical Conference on "Basic Optical Properties of Materials"	Gaithersburg, MD	May 5-7, 1980
Materials Science Conference on "Materials Science Problems in Synthetic Fuel Technology"	Argonne, IL	June 5-6, 1980
American Society for Engineering Education Meeting	Amherst, MA	June 23, 1980
ICSU-CODATA Meeting of Task Group on Thermophysical Properties of Solids	Mol, Belgium	June 26-27, 1980
Seventh European Thermophysical Properties Conference	Antwerp, Belgium	June 30--July 4, 1980
Carbon-Carbon Composites Data Bank Technical Meeting	Columbus, OH	Aug. 12, 1980
Information Analysis Centers Conference and Workshop	Washington, DC	Sept. 3-5, 1980
Twelfth Annual Symposium on Optical Materials for High Power Lasers	Boulder, CO	Sept. 30-Oct. 1, 1980
Topical Meeting on High Power Laser Optical Components	Boulder, CO	Oct. 2-3, 1980
Second Carbon-Carbon Nozzle Technology Conference	Monterey, CA	Oct. 22-23, 1980
Meeting of ASME Standing Committee on Thermophysical Properties	Chicago, IL	Nov. 17, 1980
ASME 101st Winter Annual Meeting	Chicago, IL	Nov. 17-21, 1980

TEPIAC has maintained periodic contacts with a number of national and international experts in the field of thermophysics and thermophysical and electronic properties and has developed cooperative working arrangements with a number of national and international laboratories and institutions engaged in thermophysical and/or electronic properties research for the exchance of ideas, technical information, and research results.

As part of our continuing effort to bring about improved awareness of the need and value of using evaluated reference data versus data directly taken from the literature and of the benefits to be realized through the use of Information analysis Centers such as TEPIAC, a documentary film titled "The Anatomy of Data" was produced. "The Anatomy of Data" points out and stresses the serious discord that exists among the data of science and technology as reported in the scientific and technical literature. Through on-location interviews with prominent scientists highly knowledgeable in this field, and using examples drawn from our files, the film illustrates the serious pitfalls an engineer or scientist may fall into unless he uses critically evaluated data prepared by such National Information Analysis Centers as TEPIAC. The role and usefulness of data synthesis is also stressed and demonstrated. This movie has been shown to about 202 organizations in this country and abroad.

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THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS C--ETC(U)
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SECTION VI

OTHER PUBLICATIONS NOT UNDER THIS CONTRACT BUT IN DIRECT SUPPORT OF THIS PROGRAM

In the following are listed some selected technical products produced in this same period which are not under this contract but are in direct support of this program. Thus, CINDAS' other activities have benefited this program greatly.

1. "Refractive Index of Alkaline Earth Halides and Its Wavelength and Temperature Derivatives," Journal of Physical and Chemical Reference Data, 9(1), 161-289, 1980.
2. "The Infrared Absorption Coefficient of Alkali Halides," International Journal of Thermophysics, 1(1), 97-134, 1980.
3. "The Role of a Scientific or Technical Journal," International Journal of Thermophysics, 1(1), 5-6, 1980.
4. "Problems and Procedures in Providing Values of Thermophysical Properties of Fluids," in The Technological Importance of Accurate Thermophysical Property Information, National Bureau of Standards Special Publication 590, 43-53, 1980.
5. "Absorption Coefficient of Alkaline Earth Halides," Purdue University, CINDAS Report 57, 248 pp., 1980.
6. Masters Theses in the Pure and Applied Sciences Accepted by Colleges and Universities of the United States and Canada, Vol. 24, Plenum Press, New York, N.Y., 293 pp., 1980. This has been an annual publication of CINDAS with its first volume published in 1957. A brief statistical summary of coverage of this publication is given in Table 19. Table 20 shows a complete list of academic disciplines covered by the publication.

TABLE 19. STATISTICAL SUMMARY OF COVERAGE OF "MASTERS THESES IN THE PURE AND APPLIED SCIENCES"

Volume No.	Publication Date	Thesis Year	No. of Pages	No. of Contributing Institutions	No. of Thesis Titles Reported
1	Oct. 1957	1955	108	93	1,002
		1956		93	1,027
2	Aug. 1958	1957	104	154	1,727
3[a]	Oct. 1959	1958	500	139	3,736
4	Dec. 1960	1959	443	162	4.984
5	Dec. 1961	1960	443	183	5,708
6	Aug. 1966	1961	127	186	5,911
7	Aug. 1966	1962	133	186	6,321
8	Aug. 1966	1963	143	175	6,505
9	Jan. 1968	1964	146	174	6,940
10	Jan. 1968	1965	156	170	7,310
11	Jan. 1968	1966	150	173	7,099
12	July 1968	1967	148	167	6,909
13	July 1969	1968	166	174	7,802
14	Jan. 1971	1969	151	175	7,160
15	July 1971	1970	153	183	7,413
16	July 1972	1971	152	182	7,170
17	July 1973	1972	179	250	8,513
18[b]	Dec. 1974	1973	286	251	10,381
19	Dec. 1975	1974	285	229	10,045
20	Dec. 1976	1975	293	267	10,374
21	Nov. 1977	1976	290	244	10,586
22	Oct. 1978	1977	305	255	10,658
23	Nov. 1979	1978	292	247	10,432
24	Nov. 1980	1979	293	241	10,033

[a] Volume 3 includes also doctoral dissertations for 1956-57 academic year, citing 2846 titles from 103 universities.

[b] Effective with Volume 18, the coverage has been extended to include Canadian universities.

TABLE 20. ACADEMIC DISCIPLINES COVERED BY THE "MASTERS THESES IN THE PURE AND APPLIED SCIENCES"[a]

1. Aerospace Engineering
2. Agricultural Economics, Sciences and Engineering
3. Architectural Engineering and Urban Planning
4. Astronomy
5. Astrophysics
6. Ceramic Engineering
7. Chemical Engineering
8. Chemistry and Biochemistry
9. Civil Engineering
10. Communications Engineering and Computer Science
11. Cryogenic Engineering
12. Electrical Engineering
13. Engineering Mechanics
14. Engineering Physics
15. Engineering Science
16. Fuels, Combustion and Air Pollution
17. General and Environmental Engineering
18. Geochemistry and Soil Science
19. Geological Sciences and Geophysical Engineering
20. Geology
21. Geophysics
22. Industrial Engineering and Operations Research
23. Irrigation Engineering
24. Marine and Ocean Engineering
25. Materials Science and Engineering
26. Mechanical Engineering and Bioengineering
27. Metallurgy
28. Meteorology and Atmospheric Sciences
29. Mineralogy and Petrology
30. Mining and Metallurgical Engineering
31. Missile and Space Systems Engineering
32. Nuclear Engineering
33. Nuclear Physics
34. Nuclear Science
35. Oceanography and Marine Science
36. Petroleum and Natural Gas Engineering
37. Photogrammetric and Geodetic Engineering
38. Physics and Biophysics
39. Plastics Engineering
40. Wood Technology, Forestry and Forest Science
41. Reactor Science
42. Sanitary Engineering and Water Pollution and Resources
43. Textile Technology
44. Transportation Engineering

[a] Mathematical and most life sciences have been excluded on a purely arbitrary basis simply to limit the scope of the work.

SECTION VII

CONCLUSIONS AND FUTURE PLANNING

This Annual Final Report has covered all the tasks and activities of the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) in the 12-month reporting period 1 January to 31 December 1980 and has contained details of all technical work accomplished and information gained in the performance of the contract.

TEPIAC has been maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical, electronic, electrical, magnetic, and optical properties of all important materials, and has been disseminating the resulting data and information to the entire DOD community and general TEPIAC users at large through the publication of major reference works on property data and information and of other technical products, and at the same time has been providing the much needed data and information directly to individual users through technical and bibliographic inquiry and authoritative information and data analysis services. As the objective of TEPIAC operations is to provide scientific and technical information analysis service on thermophysical and electronic properties of materials to the Department of Defense, other government agencies, government contractors, and the private sector in areas relating to technology needs, developments, and trends, it is obvious that the objective of TEPIAC operations has been achieved most successfully. In fact, the accomplishments of TEPIAC have far exceeded the requirements of the contract. Under CINDAS' operation, TEPIAC has long achieved the full operational status of a Full-Service DOD Information Analysis Center. TEPIAC has been well oriented to the needs of its user community, and its products and services are well-known nationally and, indeed, internationally.

As CINDAS operates through the multiple sponsorship of organizations having a common interest in property data and information, the results obtained from the support provided by one group benefits all others. Therefore, the supports from all other sources have benefited this contract greatly. Since the supports from other sources have been approximately equal to that from DLA, TEPIAC/CINDAS has been returning to DLA the results of two dollars of research for every dollar invested by the DLA. Thus TEPIAC has met its additional goal of achieving an annual rate of income from its products, services, and other financial supports equal to at least 50% of the initial DLA annual funding of this contract.

Due to the disturbing fact that the existing data and information on material properties recorded in the scientific and technical literature are often conflicting, widely diverging, and in many cases downright erroneous as detailed in subsection 2 of Section III, TEPIAC has traditionally stressed data evaluation, correlation, analysis, and synthesis, and the generation of evaluated reference data, even though TEPIAC is a full-service Information Analysis Center. As a result, TEPIAC can provide to its users not just the available data and information, but the evaluated correct data and information, and furthermore in many cases TEPIAC also can provide predicted data and information to the users even when the needed data and information are completely lacking and nonexisting.

In future years TEPIAC will continue to be operated as a full-service DOD Information Analysis Center using the methods and procedures developed and fully established at CINDAS over the years for the most efficient and effective service to the Department of Defense and its scientific and technical community. The past successful performance of TEPIAC assures continued future success in achieving its objective and goal and accomplishing all its tasks.

Among the tasks of TEPIAC, the preparation and publication of volumes in the new CINDAS Data Series on Material Properties is one that should gain much greater momentum, as TEPIAC/CINDAS has always felt that the maximum optimization of its efforts in serving the end-user of data and information can best be realized through the publication of major reference works. Due to the low funding level of this program, the level of effort that can be devoted to this most important task is believed far too low. It is earnestly hoped that the level of effort for the data book preparation can be increased so that more volumes of the new CINDAS Data Series can be produced in a timely manner.

In addition to volumes in the CINDAS Data Series, we anticipate that the publication in 1981 of the recently completed seven-volume merged and enlarged Basic Edition of the Thermophysical Properties Research Literature Retrieval Guide will create a most convenient reference work for the users, and that the release in 1981 of our extensive bibliographic magnetic tapes, covering both thermophysical and electronic properties, will greatly improve our dissemination of information to the DOD scientific and engineering community. Furthermore, in 1981 we plan to complete the development of our interactive, on-line numerical data bank of evaluated data on thermophysical and electronic properties, which will surely be the most welcome major addition of TEPIAC's service to the entire DOD community.

APPENDICES

APPENDIX 1. TABLE OF CONTENTS OF THE FOUR PUBLISHED VOLUMES OF THE "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"

VOLUME II-1. THERMAL ACCOMMODATION AND ADSORPTION COEFFICIENTS OF GASES

Contents

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CONTENTS

CONTENTS

VOLUME II-2. PHYSICAL PROPERTIES OF ROCKS AND MINERALS

Contents

CONTENTS

CONTENTS

VOLUME III-1. PROPERTIES OF SELECTED FERROUS ALLOYING ELEMENTS

Contents

CONTENTS

VOLUME III-2. PROPERTIES OF NONMETALLIC FLUID ELEMENTS

Contents

CONTENTS

CONTENTS

CONTENTS

APPENDIX 2

TEPIAC TECHNICAL INQUIRY QUESTIONNAIRE

________19__

QUESTIONNAIRE

(REQUIRED BY CINDAS SPONSORS - PLEASE RETURN)

FROM:

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

1. How did you find out about us? ___from previous contact, ___ a co-worker, ___TEPIAC Newsletters, ___Annual Report, ___referral from another center, ___recent publication, ___other (Explain item 8 below)
2. Did the information/data enclosed satisfy your needs? ___Very good, ___Adequate, ___Marginal.
3. Was the information/data timely to be useful? ___Yes, ___No, because: ________________________
4. Approximately how much time did the enclosed information/data save your research group? ___more than 40, ___40-30 hours, ___30-20 hours, ___20-10 hours, ___10-5 hours, ___5-0 hours
5. The enclosed information/data will be used in: ___university research program, ___military programs, ___space programs, ___civilian equipment and design programs, ___materials selection, ___input to larger research studies, ___support in-house research, ___material for publication, ___proposal preparation, ___other (Explain item 8 below)
6. Are you on our Newsletter Mailing List? ___Yes, continue sending it to me, ___No, add my name to your list. Fill out the following:
   a. Other communications of interest: ___Annual Report, ___Special announcements on publications/data tapes, ___Other (Explain item 8 below)
   b. Your professional field: ________________________
   c. Type industry: ________________________
   d. Organizational function: ________________________
      (Examples: Corp Officer, Project Management, etc)
7. Was our charge reasonable for the service (product) provided? ___Too high, ___Reasonable, ___Too low.
8. Additional Comments: ________________________

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 13 LAFAYETTE, INDIANA

POSTAGE WILL BE PAID BY ADDRESSEE

CINDAS/PURDUE UNIVERSITY
Attn: Wade H. Shafer, Asst. Dir.
2595 Yeager Road
West Lafayette, IN 47906

APPENDIX 3

SURVEY RESULTS FROM TEPIAC TECHNICAL INQUIRY QUESTIONNAIRE

Between 1 July 1977 and 31 December 1980 (42 months), 1796 TEPIAC Technical Inquiry Questionnaires were mailed out with inquiry responses to inquirers. A total of 454 questionnaires were returned; this is a 25.3 percent return. There are eight questions listed in the questionnaire (see Appendix 2). The responses to each of the eight questions are detailed below.

1. How did you find out about us?

From a co-worker	123	(27.1%)
From a previous contact	90	(19.8%)
From TEPIAC Newsletters	75	(16.5%)
From TEPIAC recent publications	47	(10.4%)
Referral from another center	45	(9.9%)
From CINDAS Annual Reports	20	(4.4%)
From other sources	54	(11.9%)
Total	454	

Typical "other sources" given in the responses are:

"Our information group"
"Our reference librarian"
"Frequent use of your publications"
"NASA Bibliography"
"TEPIAC brochures"
"NTIS brochure"
"Critical survey of data sources, NBS (Dec. 75)"
"June issue of R/D magazine"
"CRC Handbook"
"Cryogenic Materials Data Book"
"ASHRAE fundamentals book"
"Kruzas Encyclopedia of Information Systems and Services"
"At ASM Chicago Meeting 1977"
"Via North American Thermal Analysts Society (NATAS)"
"User Guide - DOD Information Analysis Center"
"National Bureau of Standards"
"Recommended by a major supplier"
"Article in May-June 1979 issue of National Defense"
"Lecture Series at Battelle"

2. Did the information/data enclosed satisfy your needs?

Very good	225	(53.8%)
Adequate	149	(35.7%)
Marginal	44	(10.5%)
Total	418[a]	

[a] "No responses" to particular questions are not included in the statistics; a total of 454 questionnaires were returned.

3. Was the information/data timely to be useful?

Yes	367	(95.6%)
No (because no data are available)	17	(4.4%)
Total	384[a]	

4. Approximately how much time did the enclosed information/data save your research group?

5-0 hours	121	(44.3%)
More than 40 hours	58	(21.2%)
20-10 hours	36	(13.2%)
10-5 hours	34	(12.5%)
30-20 hours	24	(8.8%)
Total	273[a]	

5. The enclosed information/data will be used in:

Support in-house research	108	(23.8%)
Civilian equipment and design programs	69	(15.2%)
Input to larger research studies	59	(13.0%)
Materials selection	58	(12.8%)
Military programs	50	(11.0%)
Space programs	37	(8.2%)
University research program	32	(7.0%)
Material for publication	21	(4.6%)
Proposal preparation	20	(4.4%)
Total	454	

6. Are you on our Newsletter Mailing List?

No, add my name to your list	246	(59.4%)
Yes, continue sending it to me	168	(40.6%)
Total	414[a]	

7. Was our charge reasonable for the service (product) provided?

Reasonable	285	(93.1%)
Too high	9[b]	(2.9%)
Too low	12	(4.0%)
Total	306[a]	

8. Additional Comments:

Typical "additional comments" given in the responses are:

"I was surprised that the information was found at all - let alone quickly"
"I received a very quick answer to my request for data on thermal expansion of steel"
"Very comprehensive work in your area"

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[a] "No responses" to particular questions are not included in the statistics; a total of 454 questionnaires were returned.

[b] Six of the nine responses saying the charge being too high were from university students/faculty members and small company employees.

"A tremendous amount of savings in time can be realized with the proper use of this valuable resource"
"Our own group unable to locate any references"
"We could not have done the job"
"We had exhausted all other possible sources"
"Estimate reduction of search time by 90 percent"
"We are regularly using Volumes 1-13 of the Thermophysical Properties of Matter - The TPRC Data Series; these volumes are extremely useful in our research"
"Very pleased with speed and accuracy of your reply"
"I appreciate the friendly and helpful manner you have when dealing with clients"
"Thank you for the assistance that you gave during our telephone conversation"
"You are fulfilling a very worthwhile service and we will continue to turn our service requirements your way"
"Brochures appear to have useful information to be utilized in materials selection for off shore petroleum production platforms"
"In the future I expect your service will be very helpful"
"We hope to use TEPIAC in the future"
"Our tendency is to turn to CINDAS only when all other information sources are inadequate, but it is reassuring to industries such as ours to have this back-up"
"The response from Mr. Shafer was rapid and to the point. I appreciate this type of response"
"You people write nice letters"
"This critical evaluation of research data is extremely valuable to the scientific and engineering communities"
"Appreciated the cordiality and helpfulness of Mr. Shafer"
"Your center has repeatedly been referenced as a prime source of information in my area of research"
"I forsee a need for this type of service in the future - next time I will start with TEPIAC search"
"You offer a valuable service which is much appreciated"
"Very honest and reasonable data source"
"Estimate man-hour savings at 400 hours per year"
"Saved our lab testing time more than 40 hours"
"Very pleased with searches"
"Your objectives are very important and of great help to science and engineering fields"
"Very quick response"
"The service is fast and reliable, it should be better known"
"Service is excellent"
"Your people were very helpful and I will use your organization when needed"
"Prompt service was much appreciated"
"I was very pleased with the speed of response and the personal concern for my problems shown by TEPIAC/Purdue University"
"There is value in knowing you; can't find much information on what I need"
"Prompt reliable service from a competent professional"

"Your organization was very helpful in answering specific questions and providing fast service"

"Information useful in patent litigation"

"Excellent coverage of the subject"

"Requesting engineer and librarian were impressed with speed of response and sheer bulk of data provided"

APPENDIX 4

ORGANIZATIONS USING TEPIAC INQUIRY SERVICES[a]

(In the Period 1 October 1975 to 31 December 1980)

AAI Corp.
Baltimore, MD

A. B. Chance Co.
Centralia, MO

ACRES American
Buffalo, NY

Action Research
Acton, MA

Actron, Inc.
Monrovia, CA

Acurex Corp.
Mountain View, CA

Aero Mechanical Engr. Lab.
Tucson, AZ

Aerojet Electrosystems
Azusa, CA

Aerojet Nuclear Co.
Idaho Falls, ID

Aerospace Corp.
Los Angeles, CA

Aerospace Research Applications Center
Indianapolis, IN

Air Force Avionics Laboratory
Wright-Patterson Air Force Base, OH

Air Force Materials Laboratory
Wright-Patterson Air Force Base, OH

Air Force Office of Scientific Research
Bolling Air Force Base, DC

Air Force Rocket Propulsion Laboratory
Edwards Air Force Base, CA

Air Force Weapons Laboratory
Kirkland Air Force Base, NM

Air Products and Chemical Co.
Allentown, PA

AIRCO, Inc.
Murray Hill, NJ

Air Research Manufacturing
Phoenix, AZ

Alabama A & M University
Huntsville, AL

Alabama A & M University
Normal, AL

Allegheny Ballistics Laboratory
Cumberland, MD

Allegheny Ludlum Steel Corp.
Brackenridge, PA

Allegheny Ludlum Steel Corp.
Pittsburgh, PA

Allied Chemical Co.
Idaho Falls, ID

Allied Chemical Corp.
Morristown, NJ

Aluminum Association
Washington, DC

Aluminum Company of America
Alcoa Center, PA

Amber Science Co.
San Diego, CA

American Home Foods, Inc.
LaPorte, IN

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[a] Only organizations within the United States are listed.

American Iron and Steel Institute
Washington, DC

American Thermocraft Corp.
East Orange, NJ

AMF Incorporated
Stanford, CT

Amoco Chemical Co.
Naperville, IL

AMP Incorporated
Harrisburg, PA

Anaconda Brass Co.
Waterbury, CT

Anaconda Co.
Marion, IN

Anamet Lab., Inc.
San Carlos, CA

A.P. Green Refractories, Inc.
Pryor, OK

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C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906

Technical Report AMMRC TR 81-26, May 1981,
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Electrical properties
Magnetic properties
Optical properties
Information Analysis Center
Data compilation, evaluation, analysis, and synthesis

This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1980. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. TEPIAC is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 740,000 abstracts, scrutinized 44,000 potentially good entries, identified 9,400 pertinent references, acquired 13,014 research documents, reviewed, coded, and catalogued 7,234 research documents, compiled 3,193 sets of property data, responded to 515 inquiries, published 4 volumes of data books with a total of 1,525 pages, issued 2 technical reports with a total of 144 pages, and completed 7 volumes of research literature retrieval guide with a total of 4,801 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."

Army Materials and Mechanics Research Center,
Watertown, Massachusetts 02172
THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials
C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906

Technical Report AMMRC TR 81-26, May 1981,
128 pp-illus-tables, Contract DLA900-79-C-1007
Second Annual Final Report, 1 Jan. to 31 Dec. 1980

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